POWER

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» The Engineering Profession Is Built upon the Application of Scientific Research «

Herbert Hoover

EDITORIAL

Research Meets the Challenge

POWER is the star to which civilization is hitched. Without it there would be few indeed of the comforts and facilities which surround present-day life. Although the history of power and civilization have always intertwined, developments in the art of power production in the past half century have made the two even more inseparable. Power production methods have probably advanced more in the last ten years than in any similar period of history. Because of this it has not infrequently been said that the outlook for further advance in the art of power generation and utilization was not particularly promising.

People who are fairly well informed upon the rapid changes of present-day life have been quite willing to concede the probability of advances in some directions, only to remain a bit incredulous with respect to power. They point to the small margins which measure the difference between present efficiencies of performance and the 100 per cent of perfection and speak of the increasing difficulty with which the narrowing margin may be still further decreased.

Let the skeptics then be brought face to face with the way in which scientists, research experts and engineers are meeting this challenge. Let them consider the prospects for future development in the power field as measured by the interest, thought and money being spent in all the principal countries of the world to solve the problems which in the present state of the art have been seen as obstacles to progress.

To aid in this *Power* has undertaken the collection and tabulation of research projects within the field of power production or intimately related to it. The information has been gathered from world sources and deals only with those cases known to have been completed in the past two years or still in active development.

Although their compilation and publication has been a matter of many months, it has not been found possible to include data upon some of the most important projects owing to unavoidable delays in their collection. Notable among these is a large group of English research projects, which together with the others will appear in a subsequent number of *Power*.

A study of the tabulated pages which follow will clearly indicate the directions being taken in the field of modern power research, the sponsorship and progress of the various projects and where the work is being done. It is believed that the compilation will serve all who are interested in this very important subject as a means of becoming acquainted with the work of others in their chosen field, and as a guide to their own thinking as well. To the doubter this research number of *Power* will represent irrefutable evidence of vitality of the field of power production and the consequent promise of an even better world in which to live.

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POWER Stands for . .

1. **Making Power When It Should Be Made**
2. **Buying Power When It Should Be Bought**
3. **Cheaper Power Through Modern Equipment**
4. **Easier Financing of Equipment Purchases**
5. **Better Use of Byproduct Heat and Power**
6. **Operating Methods That Save Money**
7. **Less Waste in Transmission and Application**
8. **Prevention of Smoke, Within Reason**

«We Have Become Research Minded»

Declares

A. D. BAILEY

MR. BAILEY, superintendent of generation of the Commonwealth Edison Company, is chairman of the Engineering National Section of the N.E.L.A., acting chairman of its special research committee and has long been actively identified with the research work of the A.S.M.E. Because of these qualifications he was asked to discuss broadly the dependence of modern industry on research and more particularly its relation to power engineering—EDITOR.

AS A NATION we have become research-minded, or research-conscious, individually and collectively. This applies probably as well to all civilized nations of the world in varying degree. So many of the dreams and prophecies of the past and present have come true that we attempt to "tune" our imagination to match that of the most advanced thinkers and scientists and no longer consider anything impossible; in fact we expect the impossible to happen today, or surely tomorrow. Not that we have become inventors, at least in the old sense, but rather that we have reached an appreciation of the value of research and its application, in increasing amount, in our everyday life.

The word "research," too, has increased in meaning so that in addition to investigation in pure science it is now understood to include almost every activity in which analysis and imagination are combined to develop the next logical step in the improvement of any process or any product, or in the distribution or utilization of any product. It may even be understood to include routine testing and tabulation of operating facts where these observations are the basis for future improvement. Although it may be claimed that this type of work is of a purely operating nature and should not be classed as research, it is probably true that the expense for it is in many cases included in the expense for organized research. It is accordingly classified as research work. Methods of research and the scope have changed along with the other changes that have come about in our industrial development.

Ancient Research Undirected

The human race has always been blessed with men of ambition and imagination. These, if they succeed became heroes or if they failed were relegated to those pages of history which time soon effaced. We have had philosophers who in the early days were the repositories of all learning and knowledge; we have had adventurers who, fired by curiosity or by a wonderlust, always wanted to see what lay beyond, what was around the corner; we have had scientists and inventors who generally invented things in advance of their time or its needs. These men were outstanding because they possessed qualities not enjoyed, and unfortunately sometimes not appreciated, by the great mass of their fellow men. These men were the research men of ancient times. The researcher in science worked alone amid great secrecy and mystery, and with almost mystic skill performed wonders beyond the understanding of the mass. His work was not the result of a definite need for the well-being of his fellow men; it may have resulted from the observation of some natural phenomenon or from some discovery more or less accidental. Many times, if directed at all, it was an effort to find something which would be of destructive rather than creative value.

Some of the greatest scientific discoveries resulting in the greatest advancement and benefit seem the result of chance or accident, but they invariably resulted from analysis of some manifestation of nature. We like to think of Newton watching the apple fall to the ground

or, more recently, Watt inspired by the steaming kettle which he was watching. Faraday conducting his experiments with the magnetic field and Franklin drawing sparks from a kite string become the originators of certain lines of electrical research and development. These intrigue our imagination. Others who by similar achievement have become famous in engineering and other than engineering fields are too numerous to mention here. Their example has been an inspiration. Research of the past was generally the result of some accidental discovery or the recognition of some natural phenomenon whose application to industry or to human welfare and social needs had to be later developed.

This in a way differentiates research of the past from that of the present. Nowadays a need determines the research effort and a definite objective is established before the work is undertaken. The power of analysis, however, still remains the foundation of research. While it is true that certain so-called great discoveries have been the beginning, or even the basis for, eras of great development and advancement, it is also true that our present-day civilization is the result of the solution of countless small detailed problems in modern industry. This type of research has been recognized as a requirement of modern industry, and any industry which cannot afford it, or thinks it cannot afford it, soon disappears from the picture of our present life. It is not that we have searched for substitutes for natural products; we have developed synthetic products which are physically and economically superior and which are not subject to the variations in structure and supply that are met with in nature.

SOME of the greatest scientific discoveries resulting in the greatest advancement and benefit seem the result of chance or accident, but they invariably resulted from analysis of some manifestation of nature. Under modern business conditions a need determines the research effort and a definite objective is established before work is undertaken

This is an era of big business; organization is the slogan of industry; and as research is an important part of industry it can be no exception. Research in pure science is now seldom the work of the individual, but is carried on by organized bodies or groups. Types of industrial research which apply to manufacturing processes and production continue to be conducted by the manufacturers, while other work regarding the application of products or processes on a large scale may of necessity have to be carried on by a user or a group of users. Industrial groups have seen the advantage of coordinating their work in research as they have that in other branches of industrial activity. This is particularly true of the electricity supply companies, the railways and other non-competitive industries.

The organization of research work in the N.E.L.A. and in its member companies is a good example of research coordination. In the first place, many of the member companies or groups of companies have their own research organizations engaged in routine research work or in special studies, done in some cases by the company personnel in company laboratories and in other cases at universities, technical schools or at government institutions. Occasionally the efforts of several companies or groups are coordinated in a project of more than local interest. The amounts spent by these organizations is very considerable. The research work under the direct supervision of the association, on the other hand, is rather limited and applies to subjects of general interest, such as overhead line research at the University of Michigan or underground cable research at Massachusetts Inst. of Technology and Johns Hopkins Univ.

The association also assists in special research work being conducted in geographic divisions where several member companies are involved. Examples are the work on fishways, being conducted by the Northwest Geographic division in cooperation with the United States Bureau of Fisheries; the work on Termites, being conducted by the Pacific Coast Geographic division at the University of California; and the work on radio interference at Oregon State College. In another project the association is engaged in a three-party research with steel manufacturers and fabricators. It is also contributing to research work under the direction of the A.S.M.E. and A.S.T.M. on problems of mutual interest. In addition to all this the association acts as a clearing house for all the research work of the industry.

Research work of a general nature is being organized and sponsored by the technical societies and scientific associations, and these are now getting together in the organization of work in which more than one group is interested. Duplication of expense is avoided, though there is no reduction of effort or of talent for the job. While the amount spent for research by the A.S.M.E., for example, is relatively small, yet the amount spent for research by industry under the society's supervision is very considerable. In other cases the society makes contributions to start research work while industrial support is being organized. These methods are typical of those of other technical associations. The next logical step is the formation of a general clearing house of information in research in each general field, covering the subject as a whole.

The universities and technical schools are playing an increasingly important part in research work and are increasing their facilities for handling general research subjects and problems for industry. Both educators and industrialists are finding it to their mutual advantage to work together on problems of this kind; the technical school not only learns the problems of industry and the practical application of scientific study, but it likewise receives support for laboratories devoted to industrial problems and for the training of men who will later take their place in the ranks of industry. Industry, on the other hand, learns the value of scientific study and reaps the benefit of the services of men educated and trained in research methods and with an appreciation of their practical value.

Recently at the dedication of the James Ward Packard Laboratory at Lehigh University a number of men, leaders in our great industrial organizations, spoke on the general subject, "What industry expects of the technical schools," each speaker voicing the needs of the industry he represented. These industries need men with imagination, creative thought and ambition. All expected the technical schools to train men to become clear and logical thinkers, to attain the capacity for exactness of method

and correct analysis. These are the technical qualifications for a research-minded man and as men with these qualifications are being trained in increasing numbers in our universities and in our industries as well it is small wonder that industry and the nation as a whole is getting research-minded.

Research has become the order of the day in every type of industry and in every branch, and the more highly organized the industry the more highly developed is its research organization. Yet with all this acceptance of its importance, the amount spent annually for research, although seemingly large in the aggregate, is exceedingly small compared with other expenditures of industry and particularly with the money invested in industry itself.

A recent survey that was made by the division of Engineering and Industrial research of the National Research Council shows that the average expenditure for organized research in all industries is probably less than 1 per cent of the capital invested, and that the maximum for an individual industry is slightly more than 2 per cent. Of this, the greatest part by far goes for reduction of production costs and improvement in quality of product or service, while the lesser part goes to develop new fields of application and to develop byproducts or new materials.

Reduced Time to Provide Necessities

When the marvelous earnings and the economic importance of research are considered, it is very evident that what has been accomplished is only the beginning and that the rapid social and industrial development of the past few decades is only a forecast of what may be expected in the future. Time has been speeded up until we of the present in our short span of years outlive Methuselah with his record-breaking age. The time required for providing the necessities of life is constantly decreasing, and more is thus available for recreation, education and other forms of mental and physical improvement. If this leisure time is properly used the effect will be cumulative.

With the organization and prosecution of research going on at a constantly accelerating rate, it is difficult to foretell at present what the next great developments will be.

Each new discovery and each new achievement affords a vantage point from which a multitude of new problems and opportunities present themselves. As previously stated, the greatest development of recent years has been the perfection of processing and production methods. It is quite evident that these features of industry have outstripped both distribution and utilization, and it is very evident that the next efforts should be directed along the line of greatest need, so that our industrial structure may be well-balanced and the proper economic status preserved.

There are also several byproducts of industrial progress which the engineer is duty-bound to take care of. This feature has been ably expressed by L. St. L. Pendred in his address to the Institution of Mechanical Engineers while he was their president.

"Mechanical engineers have supplied all the peoples of the earth with marvelous inventions, but we must admit that many of those inventions are imperfect. We poison rivers with effluents, charge the atmosphere with noxious fumes, jar the nerves with vibrations, deafen our ears with noises, and offend our eyes with ugly factories and a countryside destroyed by our activities. I can imagine no more beneficient work for the engineer and the scientist than the removal of all those things which still mar the great and wonderful work they have done. May all of you who are coming on to the field that we are leaving carry our work a step further towards a larger and greater efficiency than we have known, and remove the defects of applied science without diminishing the great benefits which it has conferred upon mankind."

Human Research Needed

There is, finally, the great field of human engineering. No study can be more interesting or more important than that of the welfare of mankind, the relation of man to man, the relation of the individual to industry and his reactions to various influences. Technical research has dealt with inanimate things, and, since this has been developed to such a high degree, it is highly important that consideration should be given to the effect of this and future development on man himself. If, in the end the happiness, the health and the general prosperity of mankind have not been improved, all this imagined progress will have been in vain. Until the abundance of our natural resources and the multitudinous forces of nature can be utilized to the end that this old world of ours is a better place to live in, until drudgery and worry can be reduced and finally eliminated, and until the primary necessities of life can be provided for with sufficient time for leisure—until all this is done, there will be further need for research. The engineer trained with the power of analysis and straight thinking is beginning to appreciate the importance of this field of research and in business management, in politics and in government is beginning to show his hand. These problems in human engineering must be treated with the same analysis and imagination that have characterized the work in science and industry up to the present time.

INVESTIGATION OF MATERIALS TO REDUCE Steam Turbine

By J. L. RAY

Formerly Blading Engineer With Westinghouse Elec. & Mfg. Co. Now with A. O. Smith Corp.

Steam turbine blading has been and continues to be one of the main sources of operating trouble. Although wear has never been excessive, it has necessitated enough blade replacement to justify the researches made to reduce or eliminate it

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BY BLADE WEAR is meant the abrasive and corrosive wearing away of the blade surfaces by the action of the steam and whatever foreign gases or matter that may be carried along with it. Wear caused by the rubbing of adjacent parts or by débris passing through with the steam is excepted; also average good power plant steam conditions only are considered. Wherever bad steam is used corrosion and wear are, of course, increased.

In a reaction turbine wear seems to vary in nature from point to point throughout the turbine. In the superheated regions it is chiefly of an abrasive character, caused by dust and scale in the steam. Only rarely is this wear of any consequence. At the point where the superheat is lost and condensation starts, another type of wear is encountered. Here the action seems to be mainly corrosive, and is due to chemical attack by agents in the steam on surfaces continually washed clean of the products of corrosion. A certain amount of this wear is something more than simple chemical action, as the rate is somewhat dependent on the blade velocity, being greater at the higher velocities.

Although the blade is more or less generally attacked by pitting and corrosion over its entire surface, the back at the inlet edge shows a considerable amount of water wear. Farther along in the turbine the rate of wear is found to decrease appreciably, in spite of the fact that the blade velocities are higher, much as if the chemically active constituents of the steam had become spent. In the last stages of the turbine the wear becomes almost entirely mechanical in nature, the corrosive character being practically absent. The wear in this area is almost solely confined to the back or convex side along the inlet edge, the concave and the rest of the convex surface being practically free of wear.

This action seems to be due to the blade's overtaking slow-moving droplets of water which have lagged behind the steam. Therefore the higher the blade velocity the greater the impact and hence the greater wear.

Before the days of the modern large high-blade-speed turbines, wear was not much of an item. Non-ferrous alloys of copper, nickel and other metals could be used for most of the blading in the machine and these offered considerable resistance to the type of wear encountered. As speeds became higher stronger materials were necessary and alloy steels and even plain carbon steels were widely used. A 5 per cent nickel-iron alloy was almost universally employed for several years. Although the wear of these steels was somewhat more than had been the case with bronze, it did not cause much concern until still higher speeds became common.

Although these higher-grade steels had long been used in the last low-pressure stages and had shown no serious amount of wear, it soon became apparent that their resistance to the new type of wear encountered in the intermediate regions was not all that might be desired. Manufacturers at once began searching for materials possessing high strength and at the same time good resistance to corrosion. Finally, the search narrowed down to a stainless iron containing about $12\frac{1}{2}$ per cent chromium and with low carbon content. Laboratory tests indicated that it possessed to a high degree, the desirable properties.

Cross-section of 34-in. high-speed last row blade showing A.T.V. strip soldered on inlet edge

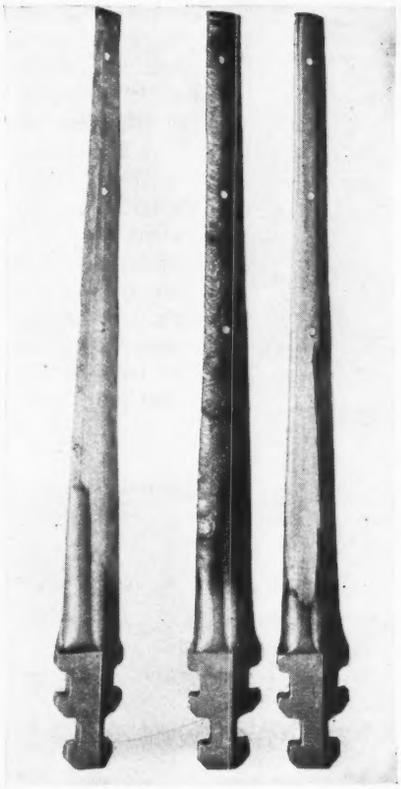
Blades made of this material were installed in the intermediate regions of turbines and after long service proved that the material was substantially resistant to wear. These blades looked practically unused after several years' service. This new blade material was then adopted generally in this country and units were completely bladed with it.

Blade Wear

Five per cent nickel steel blade with pure nickel lashing wire, showing effect of erosion

The wear problem, however, did not remain settled; at once it was noticed that in the last stage of condensing units wear took place just as rapidly as ever. One of the peculiarities was that only the last stage was affected. the previous stages being practically immune. In several high-blade-speed machines some wear has been found on the last moving row nearly down to the base of the blades, where the peripheral velocity is considerably lower than near the tip of the second last row of moving blades. It is reasonable to assume that the water concentration at the tip of the second last row of moving blades is greater than that near the base of the last row. It is therefore significant that the wear at the tip of the second last moving row, with the higher peripheral speed and with the probability of a higher water concentration, is less than that at points near the base of the last moving row, where the velocity and water concentration are less.

Stainless iron having definitely proved its worth in decreasing the wear and corrosion occurring in the intermediate region of the turbine where condensation begins, but having failed to show any marked superiority over standard materials in the last stage, it became evident that a complete investigation should be made of promising erosion-resisting materials in an attempt to discover a metal or alloy whereby the life of low-pressure blades could be increased.



The first blade has a tungsten strip soldered on the inlet edge. The other two show stellite applied by welding before and after grinding

The Westinghouse Electric & Manufacturing Company had for several years employed in its blade-test laboratory a small erosion, or wear, tester which consisted of a turbine wheel carrying flat vanes, which were the specimens under test, driven by a high-velocity jet and arranged for a counter jet of water to play on the specimens. This machine had shown a decided superiority for stainless iron over 5 per cent nickel steel which actual experience with last-row blades has now refuted. This result, with other information available, made it plain that laboratory tests of wear resistance were not dependable and it was therefore decided to conduct erosion tests on a full-sized scale in turbines in actual commercial service.

At the same time the development of laboratory testing apparatus capable of giving reliable results was begun. Efforts were directed toward the building of a machine capable of duplicating in every detail actual turbine conditions, but to date this has not been fully accomplished.

There were on the market at that time a large number of corrosion-resistant alloys, mostly of the high-nickel or high-chromium types. Most of these were known or suspected to be difficult of application as turbine blading. For instance, certain types were known to be "solder short," that is, subject to more or less spontaneous cracking and breaking during any operation involving the simultaneous application of heat and solder as in brazing or silver soldering. This is an operation necessary for the attachment of shrouds or lashing wires.

With due regard to manufacturing necessities, a list of materials broadly covering the whole field was selected and plans put into operation for placing these materials in service.

In the meantime the rate of wear of certain last rows was found to be greater than anticipated, and, at the same time, new turbine designs were contemplated employing last-row blades running at greatly increased tip speeds. It was but natural to expect that the rate of wear in the higher tip speeds of the new designs would

Low-speed blades of 5 per cent nickel steel showing the corrosive action encountered in the region of the dew point

be somewhat greater than that in the old type machines.

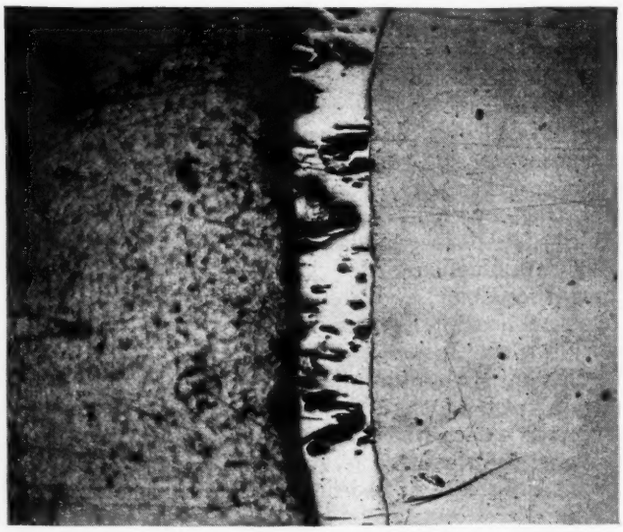
In 1927 and 1928 chromium plating was attracting attention on account of its great hardness and resistance to both abrasive wear and corrosion. The application to bronze blading used in the high-temperature regions of the turbine had previously been investigated, and it was concluded that temperature stresses would result in early failure of the plating; consequently no actual experience has ever been obtained.

Believing that conditions would be more favorable if the plating were applied to last-row blades made of stainless iron the matter was taken up again and several rows of blades were installed plated with various thicknesses of chromium. At first very thin plates were tried, which, at the time considered, were very thick as judged by usual standards. The plating process was expensive, and much development had to be undertaken. Methods for direct application of adherent plates to stainless iron were adopted and the hardness gradually improved and a reduction obtained in the relative costs of the progressively thicker plates used. Original plates were to a thickness of 0.0005 in.; now a thickness of .015 in. is contemplated. However, the maximum thickness of plate in service at present is 0.005 in. At first the results obtained were rather negative, but the thicker plates now in use have begun to show up well. Blade wear has been materially reduced, although not prevented. The plating will have to be improved with respect to porosity and the elimination of what appear to be misroscopic shrinkage cracks, which invariably are active starting points for wear.

A little later favorable reports were received concerning the results attained by Parsons with shielding strips applied by brazing to the wearing edge of the blade. The material used for these strips was an alloy known as "A.T.V." consisting of 36 per cent nickel and 12 per cent chromium. This was one of the materials we had made up into blading for service trials. We had found it extremely "solder short" and were unable to use it as blading, but strips were cut from the blades and soldered to stainless iron blades on the wearing edge for service tests.

Tests made on this alloy by blowing high-velocity jets of wet steam over the specimen did not indicate the expected improvement in wear resistance over stainless iron, but having in mind previous experience these tests were not accorded much credit. It was decided to install shields of this material on the last row of a new 60,000-kw. unit operating at 1,147 ft. per second tip velocity at 1,800 r.p.m. Later another row of blades operating at the same velocity at 3,600 r.p.m. in a 10,000-kw. unit was similarly equipped with shields.

The results shown by these two trials indicate that this shield material does not offer the expected advantage over stainless iron for extremely high tip speeds. Several other materials have been placed in service as shields and the results are awaited with much expectancy. Among these materials are tungsten, tantalum, stellite (55 per cent Co, 40 per cent Cr.), contracid (60 per cent Ni, 15 per cent Cr.), rezistal No. 7 (25 per cent Cr., 20 per cent Ni), B.T.G. (60 per cent Ni, 12 per cent Cr), Lud-



Photomicrograph of .004 in. thick chromium-plate on turbine blade surface. The black spots in the plating show a porous condition. The mottled material to the left of the plate is the supporting matrix, to the right of it is stainless steel

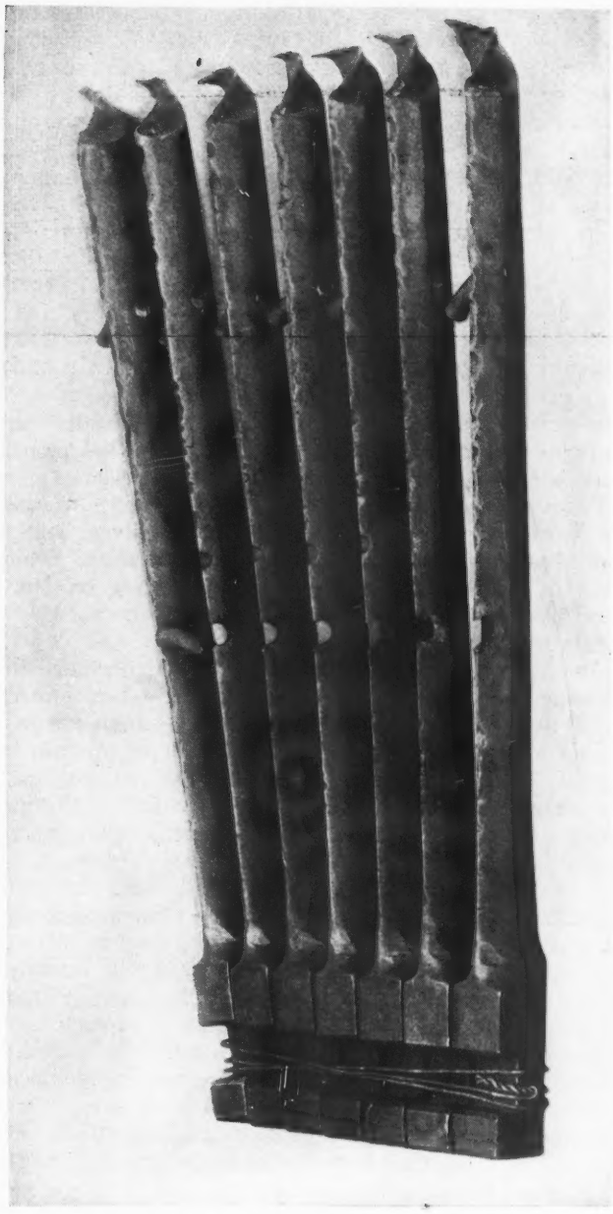
lum valve steel (15 per cent Cr, 15 per cent Ni), and K.A. 2, sainless steel (18 per cent Cr, 8 per cent Ni). Of these tantalum and stellite are the most promising.

Tantalum is expensive, but, being applied as thin narrow strips, it is required in small quantities only. Its non-corrosive properties are practically as good as those of platinum. It is tough, ductile and has a high tensile strength. By proper treatment it may be given a case nearly diamond hard. However, in that condition it is difficult to manipulate because the case is brittle and liable to fracture. Silver soldering, the method used to attach the shield strip to the blade, is accomplished easily, it being only necessary to precoat the strip with solder in a hydrogen furnace. Tantalum has been placed in service both in the hardened condition and soft. Reports of the results are not yet available.

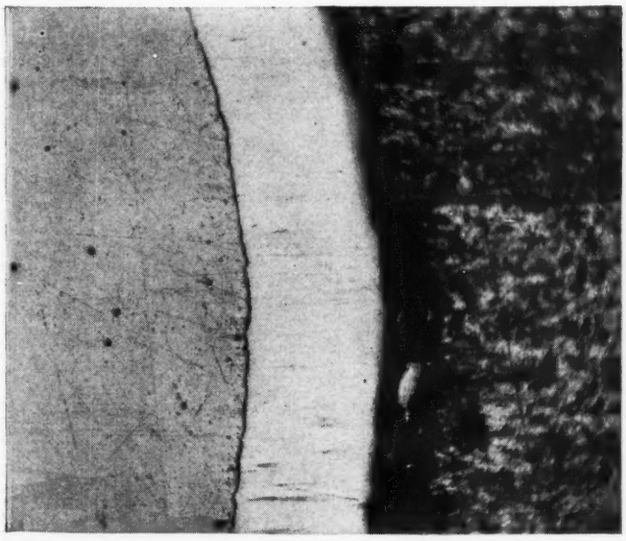
Stellite is procurable in the form of fairly thin strips, which are somewhat difficult to produce. This material is hard throughout; it possesses high strength, but little if any ductility. It solders easily, but is difficult to apply as shields, since it is somewhat solder short and is otherwise so brittle that it is easily cracked. No results are yet available as to its wearing qualities but the material as deposited by welding has shown up very well. although there may be some difference of behavior between the rolled strip material and the welded.

Welded stellite has been tried experimentally, and, as previously stated, stands up well. It is applied by running on a layer on the wearing surface of the blade with an acetylene torch. Temperatures practically equal to the melting point of the blade material are necessary to get proper adhesion, and therefore the operation is more or less detrimental to the heat-treated blade. In spite of this, stellited stainless blades have been put into successful operation by exercising the utmost care in both the treatment and the inspection of the finished blades to make positive the fitness of each blade.

Pure tungsten is being given a trial, but its poor structural condition is against it. Tungsten shields are prepared by sintering tungsten powder into a more or less crystalline ingot, which is then swaged and rolled into strips. So far the strips obtained have been laminated in



Low-speed blades of stainless steel showing comparative immunity to the corrosive action at the dew point



By accurate control of the heating process porosity can be avoided as shown by this photomicrograph of .009 in. thick chromium-plate. In this case the stainless steel is to the left of the chromium and the supporting matrix to the right

character, with a tendency to split off the blade after being soldered, leaving the bottom lamination in place. This characteristic necessitates the use of a metal of a more substantial structure; probably some of the iron or tantalum alloys of tungsten will prove more satisfactory.

Ordinarily high-speed steel, (18 per cent Tungsten, 3 per cent Cr.) in the hardened condition is said to have good wear resistance. Contracid and B.T.G., nearly alike in composition, have been tried and, after a short period of service, the indications are that neither is any better than stainless iron. Both materials are solder short and difficult to attach to blades for that reason. Ludlum valve steel, K.A.2, stainless and rezistal No. 7 have proved to be but little better than stainless iron.

In the meantime work has been progressing on the manufacture of blades of many different materials as referred to previously. The cooperation of the Duquesne Light Company and the Kentucky Electric Company has been secured and plans made to install in one of the

turbines of each company an experimental last row of blades. This row, in each case, is made of as many materials as possible so that a direct comparison may be made of their behaviors under identical conditions. The blades are installed in groups of seven or eight of the same material. Not only are different materials used, but different heat-treatments and nickel and chromium plates by different platers are included.

Included also is another type of protection not previously mentioned, that of sprayed metal. In this method the wearing portion of the blade is roughened by sand blasting, after which metal is sprayed on in much the same manner that paint is applied. By this means a coating of any thickness of adherent metal may be built up. Previous trials had indicated that this form of protection is not of much service, but it was included for purposes of comparison using silver solder, nickel, monel metal, zinc and sprayed tantalum as the materials.

For a number of years it has been the practice to coat the worn edges of steel blading with silver solder applied with a torch, to retard the rate of wear. This form of protection has been fairly effective on low-speed blades, and was also included in the general experiments for comparison.

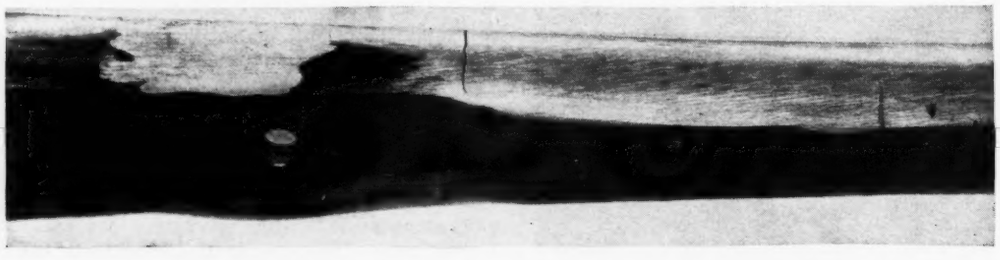
Another material, not already mentioned, included in the experiments is nitralloy. This material when treated at 900 to 1,000 deg. F. in an atmosphere of ammonia gas attains a case of great hardness, the depth of which depends on the time of treatment and the gas pressure. The case usually produced is approximately 0.030 in. thick. As this case is extremely brittle, thin parts nitrided clear through shatter quite easily; thus it is impracticable to nitride turbine blades all over. All that is needed, however, is a hard area $\frac{1}{4}$ to $\frac{3}{8}$ in. wide along the wearing edge of the blade. The rest may be left in its relatively soft condition. But it is desirable to apply some sort of protection, such as nickel plating, for if the material is not nitrided and is not otherwise protected, it corrodes easily, about like mild steel. In making nitralloy blading, therefore, all but the wearing surface of the blade is protected in the nitriding furnace. This is accomplished by heavily nickel-plating the blade all over and then grinding away the nickel where the nitriding is required and at the same time a protective coating for the rest of the blade is provided. The blade thus produced embodies an intensely hard thin strip of nitrided metal firmly embedded in the tough blade body.

The following is a list of experimental materials for resisting wear which are in service or about to be placed in service in the immediate future.

Standard stainless steel	Monel metal
5 Per cent nickel steel, ground finish	Cyclops No. 17
5 Per cent nickel steel, oxide finish	Rezistal No. 7
Stainless steel, special heat-treatment	K.A.2. stainless steel
Chromium plate (Worthington) on standard stainless steel	A.T.V. No. 1 alloy
Chromium plate (Worthington) on 5 per cent nickel steel	A.T.V. No. 3 alloy
Chromium plate (Phila. R. P. Co.) on standard stainless steel	K. E. special
Chromium plate (Phila. R. P. Co.) on 5 per cent nickel steel	Ludlum valve steel
Silver solder (torch-applied)	B.T.G. alloy
Silver solder (metal-sprayed)	Contracid alloy
Nickel (metal-strayed)	17-5 stainless steel
Monel metal (metal-sprayed)	Stellite (welded)
Zinc (metal-sprayed)	Stellite (soldered strip)
Pure nickel	Tantalum shield (soft)
	Tantalum shield (hard)
	Platinum shield
	Paladium shield
	Paladium gold shield
	Gold shield
	Tungsten shield
	Chromium plate (0.015 thick)
	Nitralloy

Of course, most of these materials and processes of application will be eliminated, but present indications are that one or two materials are going to turn out well. It will then be necessary to concentrate on them, checking the results obtained in different plants, for it is not impossible that a material which proves desirable in one place might not in another.

It should be appreciated that the increased tip speeds and lengths of low-pressure turbine blades have been the greatest factors in the development of high-capacity, light-weight, high-efficiency steam turbines. When designed for a given market, the low-pressure blades of competitive turbines will be of nearly the same dimensions and tip speeds. Inasmuch as there is little difference in the materials employed by various manufacturers, there should be no appreciable advantage of one design over another with regard to the rate of wear of the last blade row. The amount of moisture in the steam entering the last row will be the same in competitive machines designed for the same operating conditions and the same efficiency. The reduction in investment charges possible by the use of high-blade speed designs is so marked there is no doubt that the modern tendency will continue to even higher tip speeds. The investigations briefly reviewed in this paper have been undertaken in order that high-speed, low-pressure blades might be produced with the maximum possible life. It is believed that substantial progress has been and will continue to be made toward that end.



Shrinkage cracks encountered with stellite welded on inlet edge of blade extend into the body of the blade. Such cracks must be ground out and the region rewelded

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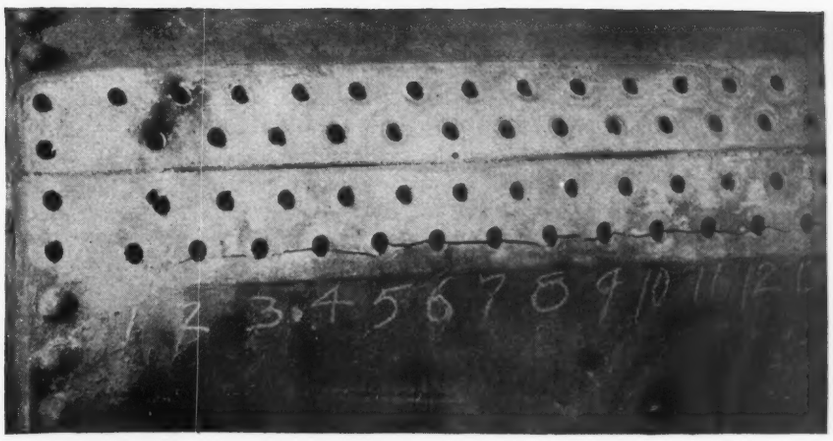
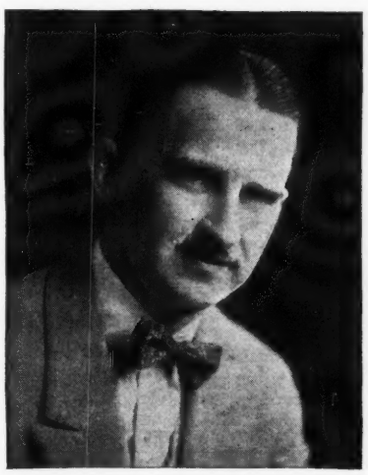


Fig. 1 — Boiler drum for 150 lb. pressure with butt strap removed to show extensive embrittlement crack between rivet holes

IDENTIFYING CAUSES OF Boiler-Metal Cracking

By FREDERICK G. STRAUB
University of Illinois



During the extensive researches on embrittlement, conducted at the University of Illinois, in cooperation with the Utilities Research Commission of Chicago, there were examined many samples of boiler metal that had cracked from causes other than embrittlement. These characteristic failures are here discussed.

▼

DURING recent years much attention has been paid to the so-called "caustic embrittlement" and there has been a tendency to say that all boiler-metal failures are due to embrittlement. Consequently, it would be well to discuss embrittlement separately as one type of failure and to classify the causes of boiler-metal failures as follows: Embrittlement, faulty metal, bad fabrication, poor design, improper operation.

Embrittlement[1]

This defect may be defined as the cracking that takes place mainly in the riveted areas of the boiler, which is intercrystalline in nature and which may be connected readily with a boiler water having high caustic alkalinity. It is caused by the action of the caustic solution concentrating in the seams and attacking the highly stressed metal immediately adjacent to the rivets. This cracking often takes place unseen and undected until the boiler is in a dangerous condition. The cracking takes place without any apparent reduction in cross-section of the plate, and the fracture resembles that of a brittle metal such as cast iron. Consequently, it has been said that the ductile boiler plate has become brittle and the term embrittlement is applied.

Owing to the fact that in the early experience with this type of boiler-metal cracking connection seems to have been made between this type of failure and failures of fabricated metal used in processes where caustic solutions were involved, as in the manufacture of sodium hydroxide, the term "caustic embrittlement" was used. It was soon evident that a relationship existed between embrittlements resulting from the use of caustic solution and embrittlement occurring in boilers owing to the fact that in the case of such occurrences the water in the boilers also was shown to be caustic. Hence the term "caustic embrittlement," which is often applied to the phenomenon, might appear to be justified, but in this discussion only the general term "embrittlement" is used.

Fortunately embrittlement cracking tends to weaken the plates slowly in the riveted areas and leaks develop. The leaky areas serve to warn the operator, and if care is taken to examine all leaky seams for further indications of embrittlement an explosion may be averted. Another indication of embrittlement is the cracking off of rivet heads. Often it is advisable to remove a few rivets to examine the plate and see if cracking is taking place

[1] A full report on embrittlement may be found in Bulletin 216, Engineering Experiment Station, University of Illinois, entitled "Embrittlement in Boilers," by Frederick G. Straub. The report did not make use of the information contained in this article.

beneath the strap. Figs. 1 and 2 indicate how embrittlement cracking takes place and illustrate the extent to which it may proceed before it is detected.

Examination of a section of an embrittled plate by means of the microscope will give an idea of how this action takes place. The micrographs shown in Fig. 3 illustrate how the cracks proceed around the grain boundaries. The cracks are shown first in the polished specimen and then after etching. Only in this manner is it possible to distinguish the cracks from the grain boundaries. Of course, if an area of the cracked plate which has been badly overstressed is taken for examination, the cracks naturally will be found deviating from this characteristic type. A micrograph of a failure caused by corrosion fatigue is shown in Fig. 4. The crack proceeds independently of the grain boundaries and is filled with the products of corrosion.

Action of the caustic in the boiler water which causes this attack on metal apparently separated from contact with the boiler water, in many cases by over an inch of solid metal, is interesting. The dilute concentration which exists in the boiler water will not affect the boiler metal. In fact, it acts in a beneficial manner in protecting the metal from corrosion and scale. In almost all instances where boilers have become embrittled they have been found to be free from scale and any indications of corrosion. The boiler water enters the small capillary crevices in the seams. Under the conditions of fluctuating temperatures and pressures in the boiler the water in these spaces slowly concentrates until a high concentration results. The concentration takes place in the areas adjacent to the rivets. The metal at these points is under high stress. The caustic attacks the highly stressed metal by penetrating between the grain boundaries.

If one were to assume that the steel were made up of a large number of grains or crystals held together by some binding material, then the caustic could be pictured as eating away this binding material and disintegrating the metal. Consequently, the metal fails free from evidence of ductility and in what appears to be a brittle manner. If the sulphate content of the boiler water is high enough the sodium sulphate separates out in the seam before the caustic becomes of sufficient concentration to attack the metal. The precipitated sodium sulphate protects the metal and no cracking can take place.

If during fabrication the boiler is so made that the seams are calked inside and left uncalked on the outside the alkaline boiler water will not enter the seams. If the solution should pass the inside calking the absence of external calking allows a free leak to develop. Under these conditions the possibility of concentration's taking place in the seams is remote. The free leak tends to wash out the seam and prevent concentration. Naturally such leaks as do develop should be stopped by inside calking.

In high-pressure boilers using forged drums the possibility of embrittlement's taking place is reduced to a minimum. There are no riveted areas, and the tube ends are the only areas liable to encounter cracking. However, proper design and rolling of the tubes should make these areas practically free from the possibility of caustic attack.

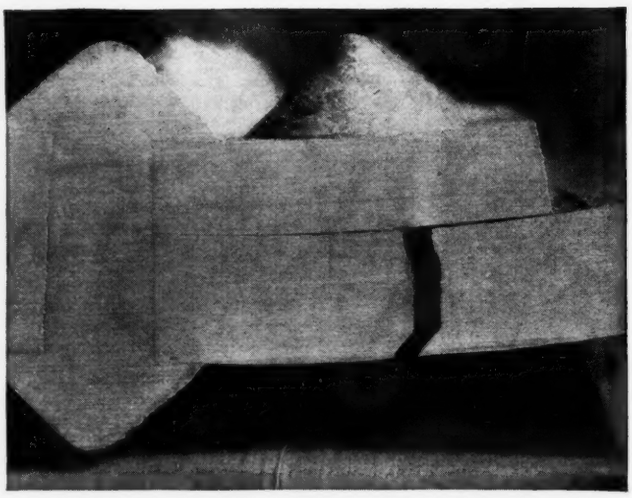
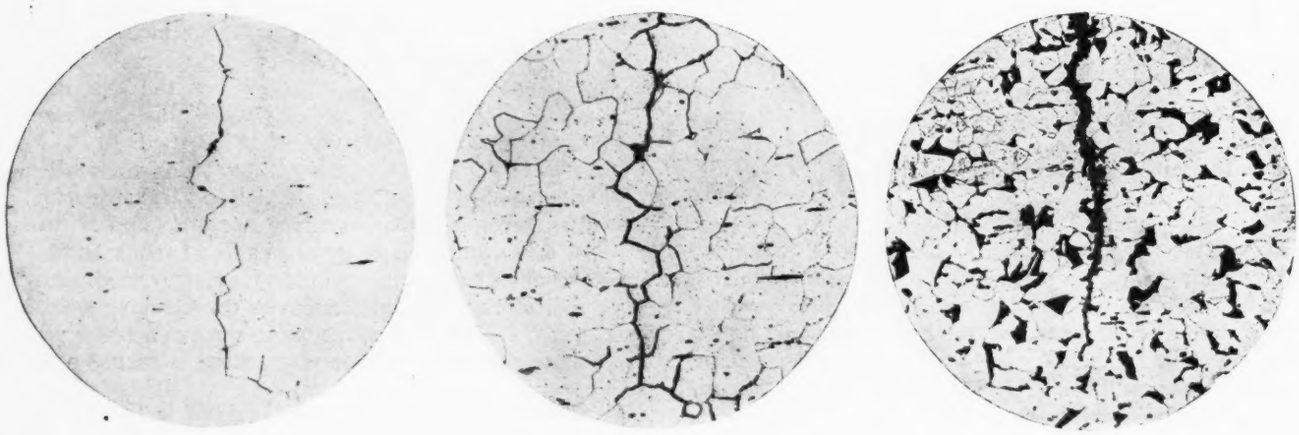


Fig. 2—Section of embrittled drum shell from 450-lb. boiler

Faulty Metal

Failures from faulty metal and flaws due to dirty steel are, in general, easy to detect. In boiler plates few failures take place from faulty metal. In a few isolated cases boiler tubes are overheated during fabrication and become brittle in operation. Fig. 5, a micrograph taken from a brittle tube, shows that the tube had been overheated during fabrication. Such a metal is naturally



Unetched 150 X **Etched 150X**

Fig. 3—Micrographs of embrittled steel

Fig. 4—Micrograph of corrosion-fatigue crack (100X)

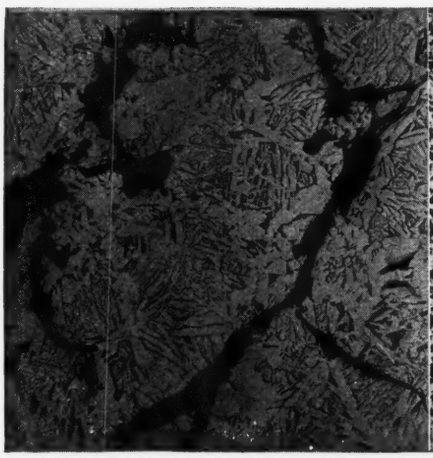


Fig. 5—Micrograph of overheated tube (50X)

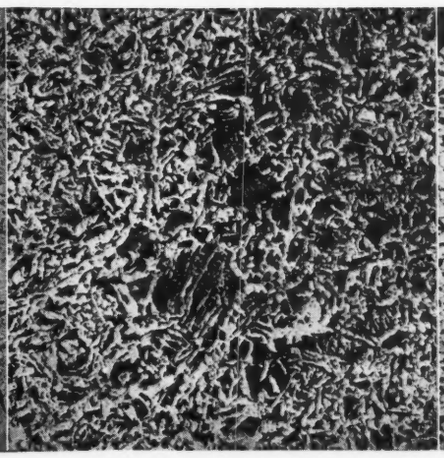


Fig. 6—Micrograph of steel showing poor heat treatment (50X)

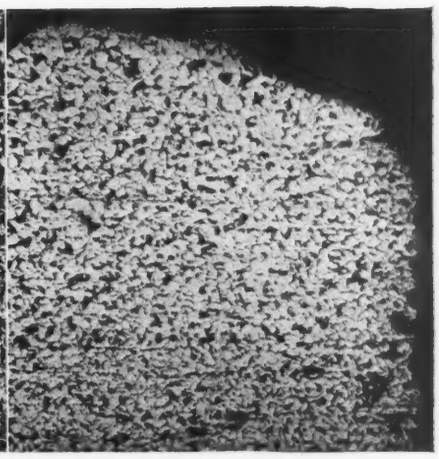


Fig. 7—Micrograph of same steel after proper heat treatment (50X)

weak. This tube was found to be laminated in such a manner that the burned portion ran parallel to the length of the tube and was covered by a fair grade of metal. However, the tube would not remain tight.

Fig. 6 shows a micrograph of a plate that cracked, and Fig. 7 is a micrograph of the same plate after proper annealing. The high temperature to which this plate was heated during fabrication left it in a weak condition. If it had been annealed properly the inherent weakness would have been eliminated.

Composition of the steel, as revealed by chemical analyses, should indicate whether the proper type of metal is being used. Thus a high sulphur and phosphorus content may be desirable in steel used for one purpose and highly undesirable for another grade of steel. In ordinary boiler plate the sulphur and phosphorus content should be low. At the same time the carbon content will depend upon the use which is to be made of the steel. Rivet stock and boiler plate usually have low carbon content. In more recently designed boilers there has been a tendency to raise the carbon content. Alloyed steels are frequently used, and the percent of the alloying elements governs the properties of the resulting alloys. Thus certain chronium steels offer a great resistance to corrosion. But cold-work may make them brittle, or improper heat-treatment may eliminate their resistance to corrosion.

In detecting faulty metal the chemical composition heat-treatment and presence of impurities, such as slag, blowholes, etc., should all receive consideration.

Bad Fabrication or Workmanship

In almost all instances of boiler-metal cracking it is possible to isolate cases of so-called poor workmanship. However, it is difficult to state specifically whether poor workmanship caused the failure. Fig. 8 is an example of what might be called poor riveting. It is contrary to all accepted practice. The holes have been punched but not reamed, and they line up poorly. The metal is not laid down properly in the seam. However, this boiler operated for many years, until it was obsolete, without any difficulty from these glaring indications of bad workmanship.

Fig. 9 also illustrates the type of workmanship used in fabricating boilers many years ago. The holes were punched but not reamed, and little care was exercised in aligning the holes. However, careful examination of these and many similar instances of poor workmanship did not reveal any indications of rivet heads failing, cracks around the rivet holes, leaky seams, etc., even after many years of operation. These cases are not cited to condone poor workmanship, since it is realized that the fabrication of all pressure vessels should be done under the best conditions possible. They do illustrate that boilers containing notoriously bad workmanship have given years of service without developing any signs of embrittlement or similar failures. This indicates clearly that poor workmanship alone never causes embrittlement.

A study of the evolution of the present-day boiler

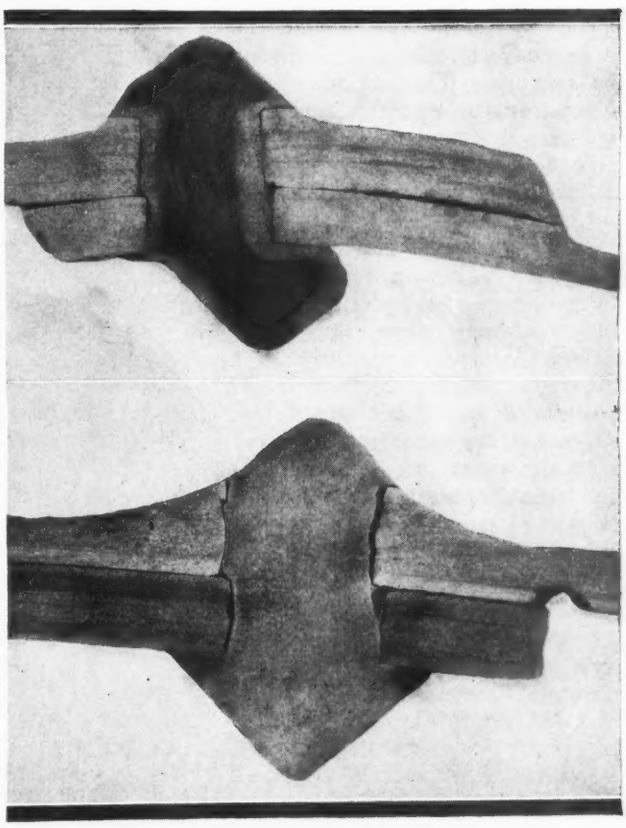


Fig. 8 (above)—Section of old lap-seam construction

Fig. 9 (below)—Lap seam badly corroded

will show many instances of poor design. The lap seam shown in Figs. 8 and 9 are glaring examples of the older design of boiler seams. The effect of corrosion upon such construction is shown in Fig. 9. There have been many cases of explosions where the lap-seam construction was used.

The old type of drum heads having a small radius of curvature is another example of poor design. Cracks developed in the knuckle, starting at the inside and working through the head for almost 50 per cent of the circumference. This type of failure, explained on the basis of high stresses developed from faulty design, has been the cause of many exposions. Newer designs eliminate the sharp bends, and, fortunately, the old type of head is no longer built.

An interesting example of cracking was encountered in a poorly designed type of superheater header. The header was suspended by steel rods, and the rods supporting the center burned away, leaving the header partly unsupported. The header bent at the center owing to the failure of the supports. Cracks started at the edge of the handholes, which were at the bottom of the header. A microexamination of the metal adjacent to the cracks revealed large grain growth. The cracks were of the peculiar type shown in Fig. 11. Further examination revealed the existence of nitrogen as iron nitride in the steel. The conclusion reached was that the cracking was caused by poor design. The metal at the lower portion of the header was subjected to excessive stress by the failure of the supports. The hot gas came in direct contact with the header as well as the supports. The metal under high tension stress and in contact with the hot gas was weakened and therefore started to fail.

There are numerous failures caused by high stresses resulting, from poor design and frequently, when conditions of operation are not the best, these failures are accelerated and it becomes difficult to say whether design or operation is the fundamental cause.

There are innumerable cases of boiler failure which may be traced to improper operation. Thus tube failures caused by having low water in the boiler or a heavy scale on the tubes may be isolated as caused by operation. The water conditions in the boiler should be under continual supervision to see that scale formation, corrosion and dirty steam are all prevented. Fig. 10 illustrates how corrosive conditions in a boiler may bring about undesirable conditions. This instance illustrates clearly how corrosion is accelerated in areas of high stress. The corrosion usually is caused by oxygen entering with the feed water. Proper deaëration should remove the oxygen. Acid waters, encountered in some localities, should be neutralized to prevent corrosion.

Many cases of burned superheater tubes may be traced to dirty steam. The steam carrying an excessive amount of entrained moisture deposits the solids in the superheater and causes the tubes to burn out. Quite often this condition is eliminated by reducing the moisture in the steam or reducing the total solids in the boiler water.

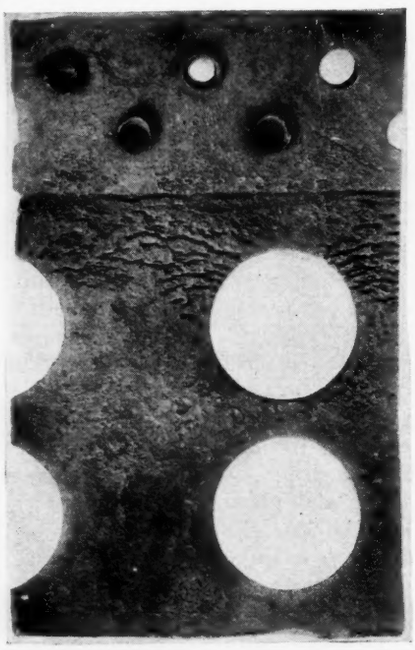


Fig. 10—Section of corroded drum

In conclusion it would be well to state that in cases of boiler-metal failures it is essential to try to determine all the possible contributing factors and to give due consideration to the possibility of any one or many of the contributing agents as causing the trouble. It would be well to eliminate all these factors when the boiler is again put in operation, even though it was decided that they were not the direct cause. Thus in many instances where embrittlement failures have taken place the operators were able to isolate poor design and workmanship along with the bad type of boiler water. However, they were convinced that poor design and workmanship alone caused the cracking, and new boilers were installed with the same type of water continued in use. In a short period of time the failure again took place in the newer boilers. If the operators also had improved the water conditions when the new boilers were installed they would have prevented reoccurrence of the difficulty.

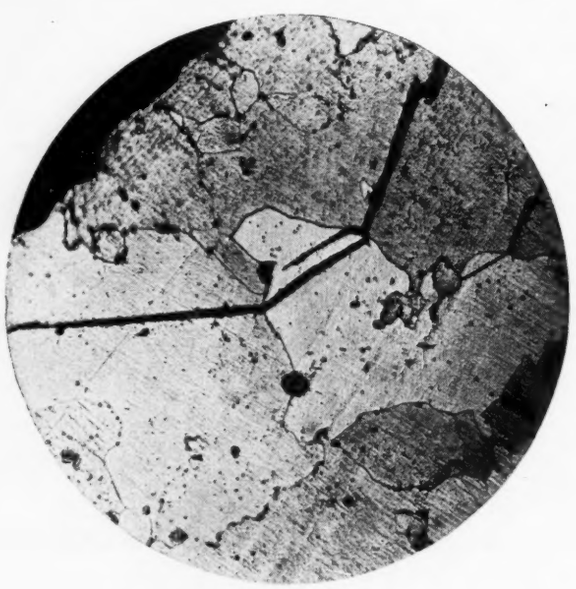
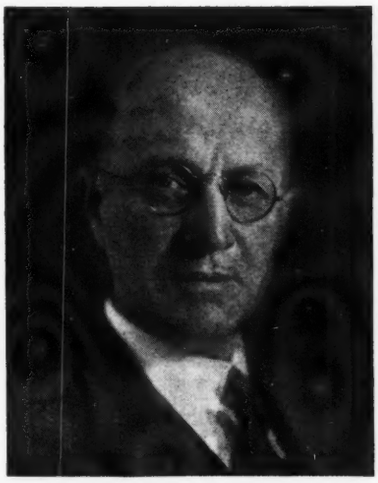


Fig. 11—Micrograph of steel from cracked superheater header (100X)

STUDY OF VARIABLES THE BASIS OF PROGRESS

In Fusion Welding



By C. A. ADAMS
Lawrence Professor of Engineering
Harvard University

Research has disclosed the importance of understanding the effects of metallurgical, chemical, mechanical and electrical variables on the art of fusion welding, and has made possible its application to power plant equipment

INCREASING temperatures and pressures at which pressure vessels must operate, together with the constantly increasing size of the units involved, has resulted in a demand for vessels of such dimensions and thickness that the older mehods of construcion are no longer commercially feasible. This applies particularly to riveting and hammer welding. Even in the case of seamless forged drums there is a limit to the total weight of metal that can be handled in the forging process. It is, of course, possible that this limit may be raised; but that would necessarily be accompanied by a considerable increase in the already high cost per pound, owing to the expensive equipment involved and to the relatively small number of such large vessels in demand. It is fortunate that the newer methods of welding have been developed so as to make them applicable to the satisfactory and economical construction of vessels in this class.

At present, in the power industry, arc welding, oxy-acetylene welding and electric resistance flash welding are employed, but of these arc welding alone seems to hold the field for wall thicknesses greater than 1¼ in., this being about the present commercial limit for gas welding. Resistance welding, on the other hand, is at present used chiefly for superheater or other coil construction. Flash welding is not at all out of the question for joints in heavy-walled drums, particularly for circumferential joints; but the cost of the equipment would be great. In fact, it would probably add too much to the cost of the structure, unless the equipment were kept in fairly constant service.

The following discussion, unless otherwise specified, will apply only to arc welding.

Welding started as a tool, the successful use of which was limited not only by the skill of the operator, but also by the understanding of the phenomena involved by those immediately concerned.

The number of variables involved in fusion welding is very great, and some of the more important ones were not appreciated in the early days. In fact, the development of some of the important applications of the art was held back many years by this lack of understanding. As often happens in other branches of industry, the failure was due not so much to the fact that men competent to solve these problems were not available, as to the fact that the problems were so little understood by those directly concerned that they did not seek assistance in the right quarters, and men who might have solved these problems were not assigned to them.

While it would be impossible and not desirable in a review of this kind to mention all of the variables involved, it may be of interest to refer briefly to some of the more important ones. They may be grouped as metallurgical, chemical and physical, the last-named covering both mechanical and electrical variables.

The physical properties of a piece of steel depend not only upon its chemical composition, but also upon its heat history, as well as upon its mechanical history, or the mechanical working to which it has been subjected, particularly after having solidified. With regard to chemical composition alone, the number of variables is large, and one of the greatest difficulties in arc welding lies in the fact that the deposited metal is not usually of the same composition as that of the rod from which it was fused. Not only do some of the elements, such as carbon and manganese, tend to burn out or oxidize, but the molten metal in passing across the arc, having a great affinity for both oxygen and nitrogen, tends to absorb these elements from the atmosphere, with the result that both of these highly undesirable constituents are almost invariably present in some degree in the deposited weld metal.

The chief mechanical problem arises in connection

with expansion and contraction due to wide temperature changes, which results in residual stresses in the vicinity of the weld. These, unless guarded against by proper technique, may readily cause fracture without the application of any external force.

In addition there are many other problems having to do with the details of the process, for example: the proper size of the electrode, the current employed for each particular job, and also the question as to the proper type of flux covering to be employed.

Although there are many machines on the market that have satisfactory characteristics for arc welding, there are important differences even in this respect which apply not only to what might be called the steady state of operation, but also to the transient state. The transient state arises from the fact that each globule of molten metal in passing across the arc from electrode to joint practically short circuits the arc, and the manner in which the machine recovers from this condition is sometimes an important factor in the result.

Finally, we have a new set of problems for each kind of metal or alloy, which are increasing constantly.

This is merely an outline of some of the important variables involved and is given for the purpose of showing that the welding field is not at all a simple one, and that the problems involved require for their solution the recognition, understanding and control of an unusually large number of variables. The time has passed when we can depend upon a welder, however expert he may be, or even upon the engineer in charge, for the solution of new problems in this field. The present state of the art has been reached only after years of careful and intelligent research work in the hands of those who are well grounded in the fundamentals of sciences involved.

In the case of boilers and certain other pressure vessels the danger to life and property resulting from failure is such as to make necessary the most stringent specifications as to their construction. In connection with this class of vessels, which will be hereafter referred to as Class I, only the highest grade of welding should be permitted.

Consider briefly the qualities of the joint desired for vessels of this class: First, they must have the necessary strength in tension, since the vessels in question are subjected to internal pressure. It is not at all difficult to produce joints with a tensile strength greater than that of the plate from which they are made, but this high tensile strength is usually obtained at the sacrifice of ductility, which in most cases is a highly important quality. Ductility means less danger under bending stress and greater resistance to shock and to alternating or repeated stresses. It has been known for some time that oxides and nitrides in the welded-steel joint increase the brittleness of the joint, but only within a very few months has a quantitative relation been established by research. The results of this research show that the tensile strength actually increases with increase of nitrogen content, while the ductility and impact values decrease in a marked degree. It is thus obviously necessary that the metal at the high temperature of the arc should be fully protected from the surrounding air during its passage across the arc. It is on this account that, for Grade A welding, electrodes must be provided with a covering which supplies a protective atmosphere or envelope around the arc. This protection may also be accomplished by the use of the shielded arc in which hydrogen or some hydrocarbon gas is projected around the arc, thus providing the necessary protective atmosphere.

Another essential property of the weld is freedom from porosity, particularly from gas pockets of appreciable size. Unfortunately, the presence of such pockets cannot be detected by inspection at the time of making the weld, neither can they be detected by ordinary tests applied to the welded joint. It is not at all likely that numerous large pockets of this kind will be produced by a first-class welder, but the danger arises from the fact that one such pocket of a size such as is likely to occur will almost certainly be the seat of fatigue failure under repeated stress application. This has been demonstrated by breathing tests on completed drums. These can be readily detected by the X-ray method, where such pockets or slag inclusions are shown on the radiograph.

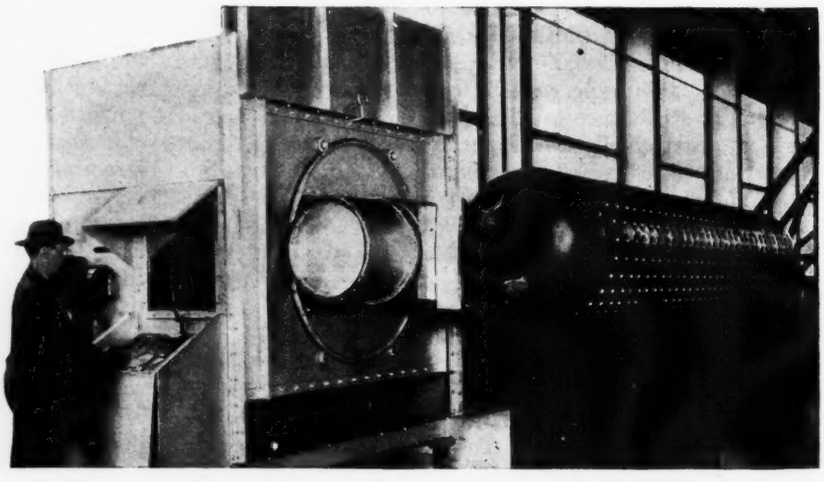
It would be difficult for anyone, however experienced in the welding art, to appreciate this danger unless he had had experience in the X-ray method of inspection. In fact, it is the writer's opinion that the perfection of both material and technique necessary to produce uniform Grade A welds cannot be developed without X-ray.

Another test for porosity is the specific gravity test, but this can be applied only to small samples of weld metal and is a wholly insufficient check on welds which may have, in a single drum, a total length of over 100 ft.

There is one other defect that cannot be detected by any ordinary test, and that is residual stresses left in the welded joint by the contraction of the metal during cooling. But it can be partly eliminated by peening each layer of weld metal before depositing the next layer. This stretches out the contracting metal and relieves, in some part at least, the residual stress. However, as there is no way of telling exactly when this neutralization has taken place completely, the completed vessel should be thermally stress-relieved, which is required in the proposed boiler code specifications for Class I vessels.

As a result of research work lasting over a period of years, there have been finally developed materials and technique which produce welds in no respect inferior to the base metal, and in most respects distinctly superior thereto; but these results cannot be obtained continuously and consistently without eternal vigilance.

Examining the fusion welded seam of a boiler drum by X-ray



MODEL TESTS INSURE

Correct Hydraulic Design

By Prof. E. BROWN
McGill University, Montreal

This article discusses the engineering and economic value of research made on models of hydraulic structures and describes the hydraulic-testing laboratory of the Shawinigan Water & Power Company at Shawinigan Falls, Que., where heads of 55 to 75 ft. can be obtained

▼

PROBABLY in no branch of engineering work are research and experiment more necessary than in hydraulics, using this term in its usual sense as meaning the science of fluids in motion. Hydraulics is indeed an experimental science, and a great deal of our knowledge depends on making tests, and the proper interpretation of the results obtained. The science of mechanics provides certain fundamental principles applicable to a particular flow condition of that abstract substance known as a perfect fluid, that is, a fluid devoid of viscosity and wholly incompressible.

Although the compressibility of water can be neglected in most problems, the flow of fluids in practical engineering work is governed by viscosity, and is so complex that conclusions drawn from principles applicable to ideal fluids must be modified to meet actual conditions. Broadly speaking, then, it may be said that the basic principles are the pegs on which to hang a discussion of the complicated problems arising in practice, and that research and experimental data must be obtained so that conclusions based on imperfect assumptions may be made applicable to actual problems.

Professor George F. Swain, in one of his books, speaks of tests in connection with engineering problems as being sometimes carried to such extremes as to become merely a substitute for intelligent thinking. It is well to be reminded in this way that tests are not always needed to forecast results, and that consideration of well-founded principles may, in many cases, lead to conclusions on which the fullest reliance can be placed. Analysis of stress in ordinary structures, for example, is a field of engineering work in which basic principles of elastic behavior of materials are directly applicable.

The general term "fluids" includes both liquids and gases, and it is now well known that the flow of air, water, oils and other fuels in pipes is governed by the same general laws. Restricting our considerations to water, it may be observed that the substance's transparency sometimes tends to hide the conditions of flow, and earliest workers in the field must have found great difficulty in reconciling experimental facts with fundamental ideas of mechanics.

Much of our knowledge of hydraulics is modern. In view of the great accomplishments in hydraulic engineering of the present day, it is difficult to realize that it was not until 1883 that Osborne Reynolds, using the color-band method, demonstrated experimentally the existence of two kinds of flow in pipes: one at velocities below a so-called critical value, and the other at velocities above the critical value. He determined the laws governing both kinds of flow for water, showing the resistance to be proportional to the velocity in the former, and to the square of the velocity in the latter. He predicted the criteria governing the flow of all fluids—liquids and gases—in pipes. The great volume of research and experimental data since gathered on the resistance of air, water, oils and other fluids in pipe lines has been coordinated on the basis of his work. He likewise developed the application of dimensional analysis in hydraulic problems. The experimental fact of the existence of two fundamental kinds of flow came first, and was followed by the broader generalizations which have been supported by the results of a large amount of later experimentation.

[1]Professor of applied mechanics and hydraulics in McGill University and in charge of experimental turbine testing for the Shawinigan Water and Power Company, Montreal, Canada.

In most cases arising in engineering practice, water flows at a velocity above its critical value. The flow is turbulent, that is, the particles do not follow regular and well-defined paths, as when the velocity is below the critical value. Mathematical theory is well developed for the latter, but for the former practice there is no theory representing actual conditions. Formulas based on imperfect assumptions must be developed, and modified in the light of experimental results which furnish coefficients for use in practical calculations.

Even in some of the simplest cases, fundamental theory alone can only predict results over a limited range of conditions. For example, the sectional area of a water jet issuing from a sharp-edged orifice flush with the sides or bottom of a tank is less than the area of the orifice. Theory enables us to predict only that it must be greater than half the area of the orifice, but a value cannot be set for it. The actual cross-section of the jet must be measured. Theory explains why the deviation from the ratio of one-half rises, but cannot forecast the quantitative result. Such examples, which could easily be multiplied, serve to show that hydraulics is to a great extent an experimental science. It rests on certain broad principles, in the application of which it becomes necessary to determine by research the values of coefficients to bring into line with actual experience basic formulas which express only imperfectly the complex conditions of flow in practice. So great is the mass of such experimental data in many fields of hydraulics, as for example in the flow through pipes, that calculations on water distribution through a network of pipes can be made with assurance that the desired results will be attained.

Use of Model Tests Increasing

This is not so in all branches of hydraulic engineering. In power development particularly, increasing use is being made of models both for the testing of hydraulic turbines and their settings, and for the effect of change of form and location of power house structures, intakes, diversion channels, dams and other parts on the river profile, both above and below the plants. Not only in connection with power development, but in studies of the effect of plans for improving navigation conditions of rivers, has the use of models been extended greatly.

The American Society of Mechanical Engineers published in 1929, under the editorship of John R. Freeman, an English translation of the descriptions of the various hydraulic testing laboratories in Europe and their work, as given originally in *Verein Deutscher Ingenieure* in 1926. This volume, entitled "Hydraulic Laboratory Practice," was brought up to date by the inclusion of accounts of later installations in Europe and America. It bears striking testimony to the nature and extent of the work undertaken, and to its great economic value. The laws of similarity and scale effect are now well known. Confidence in the value of the use of models in the study of problems in many branches of hydraulic work has been fully established, by the agreement of results in practice with those forecast from model tests. By using models to study the effect of the form of the apron of a spillway dam and on the erosion produced at the toe great savings have been made in the cost of protection. Many similar instances could be cited.

It is now recognized that the testing of models in hydraulic work is not only necessary for progress, but that when properly carried out it has great economic value. At least two large power companies on this

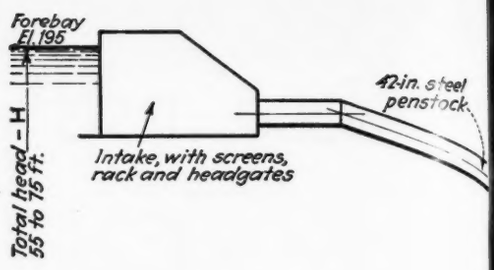


Fig. 1—Diagram of the hydraulic testing laboratory of the Shawinigan Water & Power Company

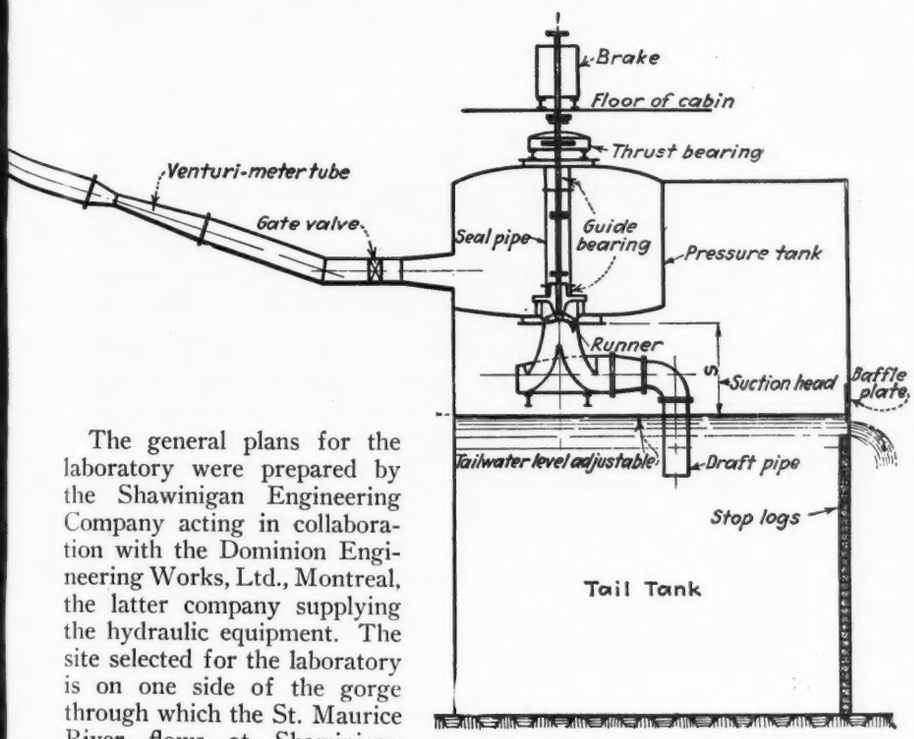
continent, the Shawinigan Water & Power Company in Canada, and the Pennsylvania Water & Power Company in the United States have established laboratories. These are for testing model turbines at power sites on their systems, so that tests may be made at heads greater than those available in the laboratories of manufacturers. The Alden Laboratory at Worcester and the testing plant at Holyoke, Mass., are well known, and the facilities for hydraulic research in the universities are being extended continually.

The sum of $350,000 has been voted by Congress to establish a National Hydraulic Laboratory and equipment for a capacity of 250 cu.ft. per second is contemplated. At the meeting of the National Electric Light Association held at St. Louis, last March, the hydraulic power committee appointed a new subcommittee on model testing. This committee is to solicit, receive and collate information regarding the testing of models of hydraulic structures, plants and equipment. It is to act generally as a clearing house for information regarding available hydraulic laboratories, their equipment and purpose. The attention focussed on this branch of hydraulic work should give impetus to model testing and produce results of great economic value in the development of water power.

The Shawinigan Water & Power Company in 1924 established at Shawinigan Falls, Quebec, a research and experimental laboratory designed primarily for testing hydraulic turbine runners at higher heads than those available in the laboratories of manufacturers. About that time rapid progress was being made in Canada and elsewhere in the use of propeller runners. This type of wheel, developing 28,000 hp. under a 54-ft. head, has been installed at Great Falls, Man., and similar units, of 30,000 hp., are being installed in the Shawinigan Water & Power Company's La Gabelle plant, where there is a normal head of 60 ft.

Propeller wheels built for these capacities and heads marked an important advance in hydro-electric practice. It was evident that certain problems involved in their successful application could only be studied where a sufficiently high head was available. Plans were therefore made for a laboratory in which model runners of both francis and propeller types might be tested. It was thought that the power companies' interests in such work was sufficient to warrant the establishment of testing facilities to supplement those of the manufacturers, which usually provide only for tests under comparatively low heads, about 10 ft. or less. The intention was to test new types of runners up to 16-in. diameter or more, under heads of 60 ft. or greater, and to study any special problems that might arise, either independently of or in cooperation with turbine builders.

Establishment by a power company of a research and experimental laboratory of this type marked a distinct advance in policy, and was an expression of the belief that valuable information would result from model tests.



The general plans for the laboratory were prepared by the Shawinigan Engineering Company acting in collaboration with the Dominion Engineering Works, Ltd., Montreal, the latter company supplying the hydraulic equipment. The site selected for the laboratory is on one side of the gorge through which the St. Maurice River flows at Shawinigan Falls. Fig. 2 shows a general view of the building penstock and other parts. The total available head at Shawinigan is 145 ft., and the laboratory was designed to use about 55 to 75 ft. of this, which means 250 to 300 hp. when runners 16 in. in diameter are tested.

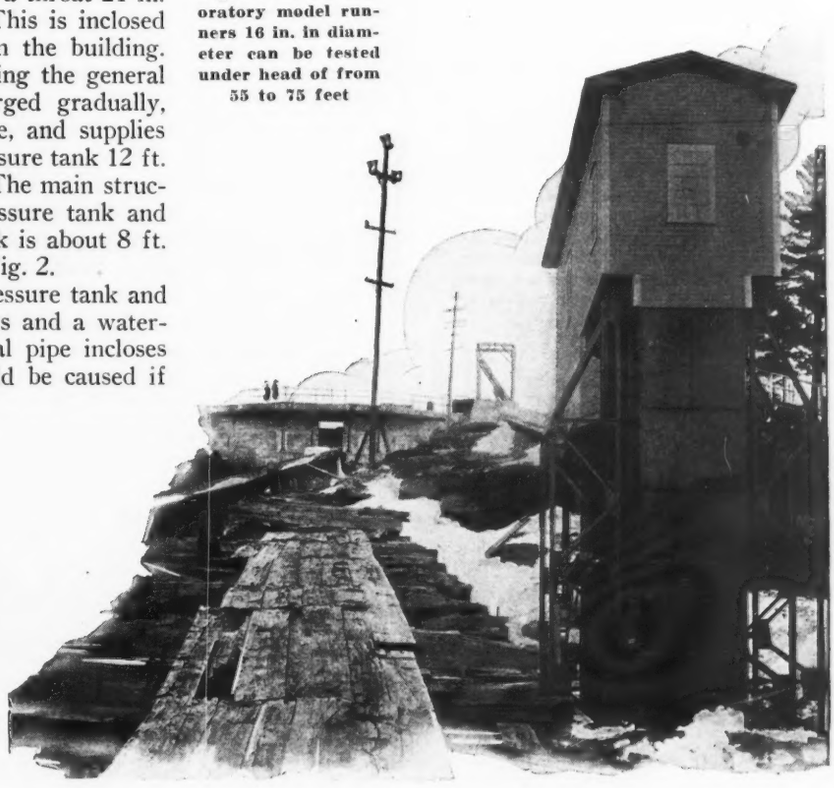
Water is supplied through a steel penstock 42 in. in diameter, about 200 ft. long, provided with a head gate, racks and screens at its entrance. At the lower end of the penstock is a venturi meter tube with a throat 21 in. in diameter, for measuring the water. This is inclosed in a housing immediately upstream from the building. Fig. 1 is a diagram (not to scale) showing the general layout. The penstock diameter is enlarged gradually, downstream from the venturi meter tube, and supplies water at low velocity to a closed steel pressure tank 12 ft. in diameter in which the turbine is set. The main structure is of steel, and consists of the pressure tank and tailrace tank combined. The tailrace tank is about 8 ft. wide and is stiffened by outside trusses, Fig. 2.

The turbine is in the bottom of the pressure tank and is equipped with the usual guide bearings and a water-cooled Kingsbury thrust bearing. A seal pipe incloses the shaft to eliminate the loss that would be caused if it were in contact with water. The turbine discharges through the draft tube into the tailrace tank, in which the water level can be regulated by stop-logs and a baffle plate. The stop-logs are inclosed within the steel structure, and the discharge takes place at the base of the tank. An extension pipe, of the same cross-section as the outlet from the draft tube, is provided so that the tailrace level may be lowered several feet below the level corresponding to an operating head of about 60 ft. By varying the tailrace level, the suction head S and the operating head H can be altered and cavitation studied.

The power developed is absorbed by a vertical-type Heenan and Froude hydraulic brake, directly connected to the turbine shaft by a flexible coupling above the thrust bearing. This brake, together with all gages and handwheel for operating the turbine gates, is in a wooden cabin extending above the steel structure and over the lower end of the penstock.

All tests to date have been with models of propeller-type runners, and many different problems have been studied. In early installations, in which spreading-type draft tubes with a high central cone were used, trouble was experienced both by the cones breaking and by erosion of concrete at the draft tube's surface below the runner's discharge elevation. Tests were made without a cone and with cones 6, 16 and 32 in. high, the latter being the full height up to the runner. These tests showed, in general, an advantage for the 32-in. cone at the largest gate openings, and up to a certain speed, beyond which the advantage was less marked. At very small gate openings the 6-in. cone gave the best results at all speeds. These statements apply to tests made with a certain form of runner, and are subject to modification if operating conditions are changed. The tests indicated, broadly, that no one cone shows to advantage in power and efficiency at all gate openings, and that only at the larger gate

Fig. 2—In the laboratory model runners 16 in. in diameter can be tested under head of from 55 to 75 feet



openings does the highest cone offer consistently higher efficiencies than the others.

A great variety of tests have been made at the plant, which may be included under the general headings:

1. Distribution of velocity and pressure in draft tubes.
2. Study of conditions governing pitting.
3. Resistance of different materials to pitting.
4. Effect of draft-tube form.
5. Effect of admitting air.
6. Determination of power-efficiency characteristics on a series of propeller runners with differently shaped blades, and the relation of runner setting to such characteristics.

Space does not permit discussing all of these problems. The last-named bears on runner selection for a particular project, and has a direct economic value. In low-head plants the head varies considerably, owing to changes of forebay and tailrace levels during periods of flood. These variations affect both output and efficiency, and it is necessary to know not only the runner's performance at normal head, but what the power output will be under reduced heads. Efficiency in the latter case is relatively unimportant, as water is being spilled. The runner's elevation with respect to tailrace level is important, as it affects the unit's performance and the power house cost.

A so-called cavitation factor is involved, defined as $(H_b - S) \div H$, where H_b equals barometric height in feet of water; S equals elevation of the discharge tips of runner above tailwater, measured in feet; H equals operating head in feet. By altering the tailrace level (see Fig. 1) the values of S and H can be changed and the cavitation factor varied over a considerable range. At the lower values of H the runner is below tailwater level, and at the higher values it is above that level. As H is increased the cavitation factor is reduced, and such reduction ultimately affects the efficiency. Complete tests for power and efficiency of a given runner are therefore made over a predetermined range of speed, starting with the lowest operating head, which corresponds to the highest cavitation factor.

The head is then increased and the margin against cavitation decreased by lowering the tailwater level. The series of tests is repeated, and the same procedure followed at higher and higher heads. It is then possible to determine the limiting conditions under which the efficiency begins to suffer. From such a comparative series of tests for runners with different types of blades the most desirable type can be selected, having in mind the power-efficiency characteristics for the range of operating heads in question and the behavior of the runner as regards cavitation.

It is generally accepted that the marked drop in efficiency which occurs at some point as the cavitation factor is progressively reduced is a sign that cavitation is present, with the attendant danger of pitting. The cavitation factor, under operating conditions at the proposed plant, should be well above that at which there is a marked loss of efficiency.

After selecting one or more runners, as described, comparative tests of their relative merits as regards erosion can be made by observing the extent to which the painted surface of the draft tube is affected by operating the runners for equal periods of time under conditions corresponding to those which would arise at the proposed plant. This method of using painted surfaces for the detection and comparison of erosion effects has proved satisfactory. The procedure described was followed, acting in conjunction with the Dominion Engineering Works, Montreal, and I. P. Morris & De La Vergne, Inc., of Philadelphia, in the selection of the propeller runner recently installed in the fifth unit at La Gabelle on the St. Maurice River, Que.

In addition to the work of testing of runners and studies of the general problem of cavitation, comparisons of the flow in the penstock have been made using (1) venturi meter in the penstock, (2) Allen salt-velocity method, (3) Ott recording current meters at the intake.

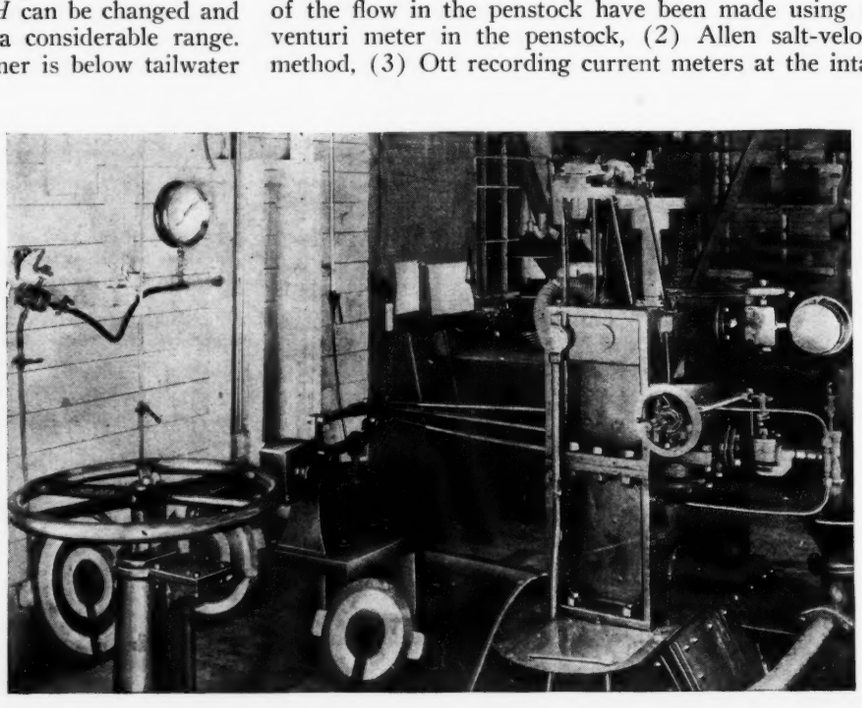


Fig. 3—Under the head available a model runner 16 in. in diameter will develop from 250 to 300 hp. This power is absorbed by a vertical-type hydraulic brake, directly connected to the turbine shaft by a flexible coupling above the thrust bearing. This brake, together with all gages and the handwheel for operating the turbine gates is in a wooden cabin extending above the steel structure over the lower end of the penstock.

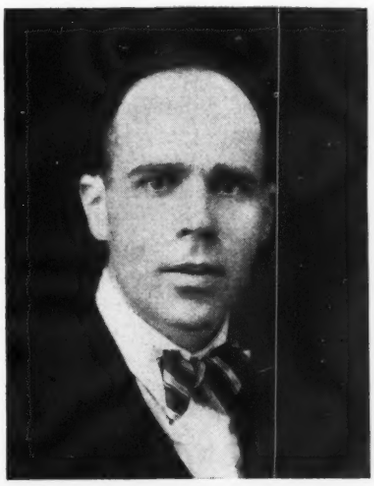
The value of tests of models is recognized by all connected with water-power development, and it appears that an increasing use of the testing facilities available will contribute greatly to the progress of the hydroelectric industry. There is ample scope for investigation work, both along general lines and in the case of specific projects. The combined resources of national laboratories and of the laboratories of manufacturers, power companies and the universities should aid greatly in solving the many problems which arise.

SOLID-INJECTION DIESEL DEPENDS ON

Fuel-Spray Research

Oil-spray and combustion problems accompanied the development of the solid-injection diesel. While European engineers have given more thought to physical research on fuel oils, the studies at Langley Field and Pennsylvania State College on spray formation are outstanding in their scope and tangible results

By P. H. SCHWEITZER
Pennsylvania State College



DIESEL ENGINE research is comparatively new in this country, for while the earlier builders did considerable development work their investigations were specific and unrelated. It is only in the last ten years that systematic efforts have been made to explore the laws governing the phenomena in an oil engine by the experimental method, and to furnish designers with scientific data to take the place of the former cut-and-try plan.

There are two excuses for the apparent neglect of the domestic oil-engine research. The development of the oil engine abroad preceded that in this country and we were satisfied mainly to follow in the footsteps of the foreign builders. Furthermore the air-injection diesel engine gave very little trouble and hence offered little incentive for research. Thermal performance was from the beginning about as good as could be expected.

Recently, however, two factors have given stimulus to oil-engine research: the development of airless injection and the desirability of employing higher rotative speeds.

From its inception airless injection has had a strong appeal for both makers and users, but at the same time it has brought up a number of problems regarding atomization, spray formation, coordination of spray and combustion chamber and the effect of turbulence. It was recognized early that without a lucky or methodic coordination of these elements the airless-injection engine would not give satisfactory results.

These problems were still awaiting solution when endeavors became manifest to speed up the diesel engine from 200 or 300 r.p.m. to gasoline engine speeds of 700 to 1,500 r.p.m. In this endeavor severe difficulties were encountered. The first of these was the accurate metering of minute quantities of fuel. A 50-hp., six-cylinder, two-stroke-cycle engine of 1,000 r.p.m. when idling has to be fed 0.00002 lb. of oil at every revolution to each cylinder; this occupies a volume somewhat less than a $\frac{3}{32}$-in. cube in size. It may be admitted right away that it was the advance in precision machine-shop practice, not scientific research, that solved the metering problem.

The other difficulty encountered in speeding up the

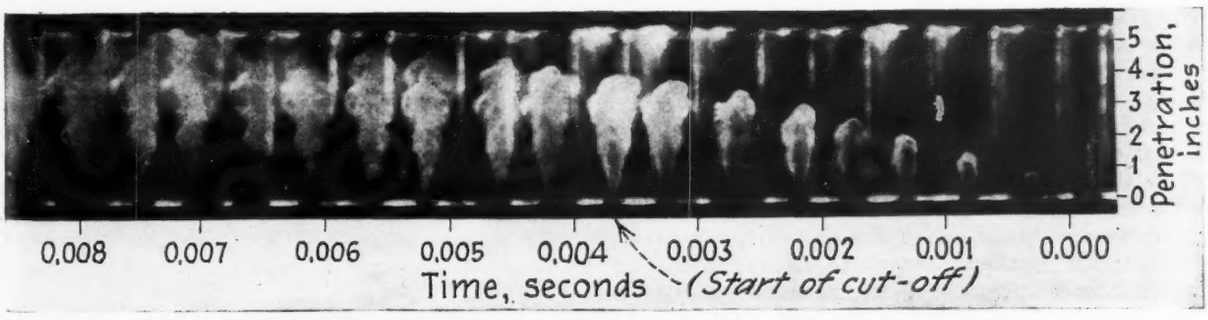


Fig. 1—Centrifugal spray, injection pressure 8,000 lb. air chamber pressure atmospheric

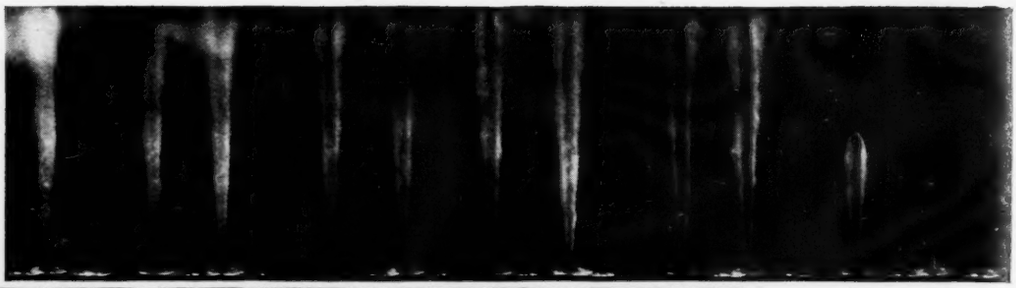


Fig. 2—Non-centrifugal spray injected at 8,000 lb. per sq. in pressure into a chamber under atmospheric pressure

Fig. 3—Non-centrifugal spray injected at 8,000 lb. per sq. in. pressure into a chamber at 200 lb. pressure

diesel engine is more inherent in the engine type. While a gas- or gasoline-engine cylinder is fed with a prepared fuel-air mixture ready to ignite and to burn, in a diesel engine raw oil is introduced at the end of the compression stroke and has to be atomized, heated up, mixed with air in a combustible proportion, and ignited and burned during a fraction of a revolution, which in a high-speed engine takes only a few thousandths of a second. The delay in ignition caused by the necessary heating up of the oil particles is harmful to the operation of the engine. Hence in addition to the numerous problems of bringing oil and air into intimate contact in the combustion chamber, in a high-speed engine the problem of reducing the ignition lag is added.

During the short period of its existence, scientific oil-engine research has contributed a great deal to our understanding of the compression-ignition engine.

The Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics found by the method of high-speed photography that the spray formation in compressed air differs considerably from that in free air. The spray is finer and wider in dense air than in atmospheric air and possesses only a fraction of its atmospheric penetration. This observation gave an impetus to studies of oil sprays under engine condition. It was discovered that the density of the gas in the chamber is the deciding factor in regard to spray formation; this means that the spray will behave alike in different gaseous mediums, such as CO_2 or air, and under different pressures and temperatures, so long as the density is the same. This discovery opened the way for studying the oil spray in cold air at 200 lb. per square inch in lieu of hot air at 450 lb., as encountered in the actual engine.

At Pennsylvania State College further studies were made on the dispersion and penetration of oil sprays under engine conditions. It was found that the total penetration of the jet does not increase when the injection pressure is increased from 2,000 to 4,000, or even 8,000 lb. per square inch. This paradoxical result is explained by the fact that in addition to greater initial velocity the higher injection pressure also produces a much finer atomization; although starting out with a higher velocity, the smaller globules encounter an increased air resistance and the two effects about balance each other. Use of higher injection pressures to obtain greater penetration is useless. But by the use of a thicker oil or lower chamber pressure the penetration can be increased appreciably.

These results have a direct application in the moderate-turbulence, or open-chamber type, of engines. The air being nearly stagnant, the oil spray has to reach all of the air in the combustion chamber and make use of every oxygen molecule available; otherwise we waste fuel or air (piston displacement) or both. The spray has to fit closely the combustion chamber. If the dispersion is such that air pockets in the chamber avoid contact with the spray, that air escapes combustion altogether and this results in low mean effective pressures. If too much oil accumulates in certain parts of the combustion chamber the fuel particles starve for lack of oxygen and leave the cylinder unburned. The result is smoky exhaust and high fuel consumption.

The same effect is frequently caused by permitting the fuel spray to hit the cooled metal surfaces of the cylinder wall. Either precipitation or cracking of the oil will occur resulting in carbon deposits and loss of efficiency.

The spray must not have a length greater than the combustion chamber can accommodate and it must be so distributed that it fits the existing space. To achieve this object multi-orifice nozzles with small holes are generally used in moderate-turbulence engines. But in the very small cylinder sizes the sprays cannot be made short enough. The combustion space of a 5x7-in. diesel cylinder is a disk $\frac{1}{2}$ in. high and 5 in. in diameter. But the smallest plain sprays produced still penetrate 10 or 15 in. into the combustion chamber.

To reduce the penetration and improve the dispersion, centrifugal nozzles were studied, in which a whirl was imparted to the spray by helical or tangential grooves before leaving the orifice. The National Advisory Committee for Aeronautics found that a whirling of the spray effectively cuts the penetration; in fact, so much that it makes centrifugal nozzles unfit for large-sized engines. The dispersion of the centrifugal nozzle over the plain nozzle did not show the same improvement in compressed air as in atmospheric air. In dense air a plain spray opens up, the cone angle becoming wider; while the centrifugal spray closes up like a rosebud. These observations made the field for centrifugal sprays rather limited.

The effect of the air density and of the centrifugal

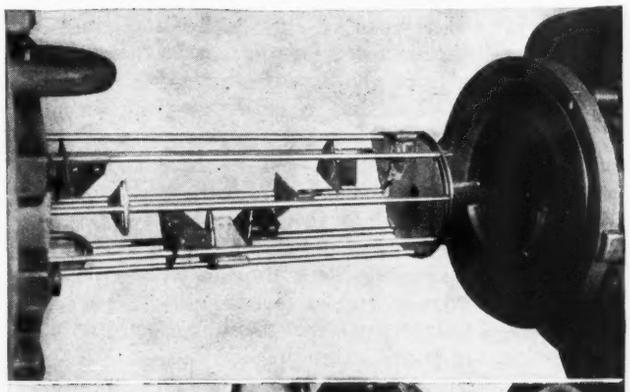
grooves in the nozzle can be plainly seen from Fig. 1.

Another way of obtaining a desirable mixture of fuel and air in the short time available is by giving a motion to the air. This principle is used in the high-turbulence engines. They either employ ante-chambers with narrow throats or displacer pistons that cause violent air flow, or directing vanes for the intake air to cause a rotation of the air in the combustion chamber. In fuel consumption the high-turbulence engines are behind the low-turbulence type, mainly because the production of air turbulence ordinarily increases the friction horsepower considerably, as was ascertained by the N.A.C.A. But they have a number of attractive features, such as their greater adaptibility for variable engine speed.

By spray photography it was shown that even a strong air flow is unable to deflect the body of a spray produced by several thousand pounds' injection pressure. Only the insignificant fringes of the spray are torn away by the wind, the shape of the spray remaining essentially the same. This is not to be wondered at when it is considered that the oil spray has a velocity of several hundred feet per second and trying to deflect it is just like blowing on a bullet.

Imparting a rotation to the air charge around the cylinder axis was found by the N.A.C.A. to be the latest extravagant way to create an air turbulence for improving combustion. At present more and more engine builders are adopting this method. In such combustion chambers, as well as in the non-turbulent type of chambers, the shape of the spray and the distribution of the fuel particles within the spray plays an important rôle. The dispersion tests conducted at Pennsylvania State College make a proper coordination of spray and combustion chamber easier.

Fig. 4—"Spiral Stairway" used in the Penn State dispersion tests to determine spatial distribution



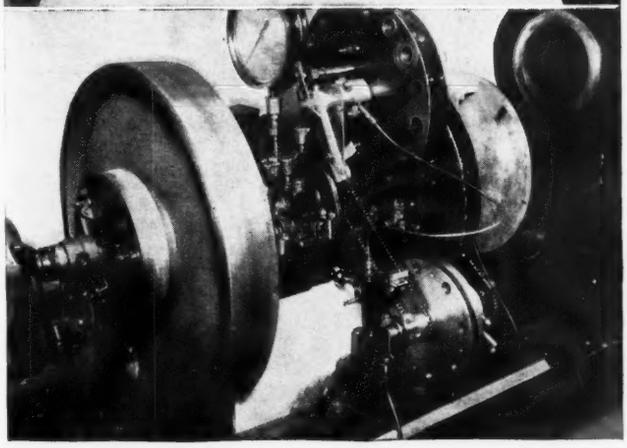


Fig. 5—Investigating the time distribution and after-dribbling of spray of an injection-pump-nozzle assembly with the spray stroboscope

The fuel injection compression-ignition engine is very sensitive to the timing of the injection. The transmission of the pressure through the fuel line is not instantaneous, but a certain time elapses between the beginning of the injection by the pump plunger or injection valve and the appearance of the jet at the orifice. The N.A.C.A. found that the propagation velocity of the pressure wave is independent of the pressure and tube size. It is approximately 5,000 ft. per second. Therefore, for uniform ignition timing in a six-cylinder engine of 500 r.p.m., the pump of the sixth cylinder that has a five-foot-longer injection line needs an earlier timing by 0.001 second, or three degrees crank angle, than the pump of the first cylinder.

It was discovered at Pennsylvania State College that elasticity of the injection valve stem has also a great deal to do with the injection timing and with the rate of fuel discharge. Builders of solid-injection engines were frequently displeased by sharp-pointed indicator cards. Attempts to eliminate undesirable high maximum pressures by changing the fuel-cam profile did not meet with much success. Making the seat smaller and the valve more rigid is likely to produce the desired effect.

A common annoyance with solid-injection engines is the so-called after-dribbling. The fuel injection instead of being cut off sharply continues at a diminishing pressure with poor atomization, causing imperfect combustion and black exhaust. Stroboscopic investigations at Langley Field and Penn State found the causes and remedies for after-dribbling. Vibrations of the valve stem and pressure oscillations in the line frequently produce secondary discharges, which have the appearance and effect of after-dribbling.

To improve the volumetric efficiency a study was made by the Westinghouse Electric & Manufacturing Company on the effect of long suction lines, which were found economically superior to charging blowers. Lower exhaust temperatures resulted from the use of supercharging intake pipes. At light load the thermal efficiency is higher without the inertia suction pipes, but at high loads the test results justify their use. Calculations were checked by suction cards taken by an electrical membrane indicator.

Experiments carried out by the Emsco Aero Engine Company showed the close relation which exists between the rate of pressure rise and engine knock. They also verified the assertion that an increase in compression ratio eliminates the knock in a diesel engine, instead of increasing it, as is the case in gasoline engines.

An experimental study of the fuel-injection engine with spark ignition was made recently at Massachusetts Institute of Technology. The conclusion was drawn that a replacement of the carburetor by a suitable injection device increases the volumetric efficiency and the output of the engine by over 10 per cent and substantially lowers the fuel consumption.

The development of solid-injection engines, especially those of medium and high speeds, revealed that all fuel oils did not burn with the same characteristics. The necessity of discovering those characteristics that make an oil undesirable led to the formation of a Diesel Fuel Oil Research Committee by the American Society of Mechanical Engineers. Under the sponsorship of that committee a number of long field tests have been conducted on oils with varying carbon residues and viscosities.

DETERMINING CAUSES OF

Condenser Tube Corrosion

By BERT HOUGHTON

Operating Superintendent, Brooklyn Edison Co., and Vice-Chairman, A.S.M.E. Research Committee on Condenser Tubes

THE formation of the Special Research Committee on Condenser Tube Corrosion of the American Society of Mechanical Engineers fundamentally grew out of a conviction by many operators of condensers that replacements of condenser tubes were entirely too frequent and that the cost of maintenance was excessive. Secondary aspects of the situation were that much of the research was somewhat sporadic and isolated, and should be coordinated. Another factor was that many of the tube manufacturers and customers had reached an impasse regarding the causes of tube failure, these customers contending that failures were due to faulty tube manufacture, while the manufacturers contended that failures were due to conditions outside their control.

Under such circumstances it seemed fitting that a committee composed of representative condenser and condenser-tube manufacturers, large customers and interested research organizations be set up to make a thorough investigation of the causes of failure and to determine ways of increasing tube life. This committee was organized in May 1925.

There were several phases that immediately presented themselves. First it was obvious that a detailed survey of the country was necessary in order to determine the extent and rate of corrosion in various sections, the character of failures, and the character of circulating water. This investigation included reports from many large and small users throughout the United States, including tide-water, fresh-water and intermediate installations. It brought out the geographical location of bad condenser water conditions and showed that generally speaking those plants which had to use harbor water had the greatest difficulty, although many fresh-water plants did not escape corrosion troubles. It also appeared that on tide-water installations Admiralty brass was in common use, while on the fresh-water installations both Admiralty and Muntz Metal were found.

Microscopic examination of failures from various sources was considered advisable to determine as far as possible the part played by faulty manufacture, also the examination of the faults and the products of corrosion might well indicate the cause of failure. In this connection it was necessary to classify the types of failure, and the following classification and nomenclature was set.

General thinning or general corrosion—The inside surface of the tube is evenly corroded without the formation of pits or dezincified spots. Little or no basic salt on the tube.

General dezincification—The tube is generally not thinned down to any considerable extent. The zinc is taken out, leaving a mass of spongy and more or less brittle copper behind. This shows, when broken, a red or bricklike fracture extending from the inside partly or completely through the tube wall. It is frequently more or less irregular, so that the tube wall is completely dezincified in places and in other places partially.

Deposit attack or pitting—Small, round pits or pinholes beneath green salt and cuprite. Foreign deposits often accompany this type of corrosion. When these pits or pinholes contain plugs of copper, this is known as "Plug Type" dezincification.

Tailed-type pitting—Pits formed by the removal of the scale and having a deep section at the upstream side and a shallow tail at the downstream side.

True erosion—The tube is worn away by the action of solids in the circulating water, often accompanied by corrosion.

Impingement attack—Corrosion caused by air bubbles and generally confined to the inlet end of tube. This may be uniform thinning or it may appear as grooving.

Scale thinning—Scale kept thin by chemical action, resulting in corrosion and in isolated pits.

Solution—Scale absence due to the presence of acids, etc., resulting in general thinning.

Splitting and season cracking—Splitting in a longitudinal plane caused by internal strain in the tube metal or undetected defects within the tube walls. Season cracking may be due to the same cause as splitting, and in addition may be due to stresses set up in expanding and rolling the tube ends in the tube sheets.

It was felt that cases of tube deterioration that were confined entirely to the inlet of the tube might be due largely to turbulence of the circulating water. Investigation of the water flow at the tube inlet indicated that although ferrule design is a very important factor in removal of turbulence, quiescent flow of water can be attained only by the removal of turbulence factors all along the line. The intake tunnel should be of sufficient size to allow for a comparatively slow movement of the water. The pump suction and circulating pump must also be designed to reduce turbulence to a minimum. Circulating pumps are frequently a great source of turbulence, this factor often being entirely overlooked in pump design.

Pump glands should be well sealed to prevent the infiltration of air, which not only creates turbulence, but acts as a corrosive agent. The inlet to the condenser should simulate a cone so that the entrance to the condenser is gradual and the change in direction of the water slow. Continuing this principle, water boxes have been designed which present a smooth surface to the circulating water. Ribs, stay-rods and bolting are so placed and so covered that stream flow is not disturbed.

Ferrules have received consideration for many sources for a number of years. It is evident, however, that, if the tube is to benefit from the careful consideration given the design of equipment up to this point, smoothness of ferrule contour is of the greatest importance. The usual ferrule with its wrench slots creates turbulence. An unslotted ferrule, fitting the tube with a tight metal-to-metal joint, and so belled that the turbulent action due to the vena contracta is reduced to a minimum, will eliminate eddy currents and reduce this type of corrosion.

Study of steam flow and condensation progress has developed marked improvements in condenser design, resulting in increased condenser efficiency. Many condensers have been installed that were really no more than bundles of tubes. Experiments have shown that condensing is not merely a matter of surface and steam baffles, but depends on an arrangement of tubes, air off-takes and air baffles that will eliminate pockets, distribute the load through the installed surface and prevent clogging in otherwise overworked areas. Sectionalizing is an important feature, as by this means the steam flow may be properly proportioned. In several cases vacuum at the turbine exhaust has been improved by approximately one-half inch of mercury by intelligent removal of 20 to 25 per cent of the tube surface.

Reduction of turbulence, proper air venting of water-boxes, ferrule and pump design, on the water side of the condenser, as well as condenser sectionalization, proper steam laning, design and location of air off-takes and baffles on the steam side, are principles that I have advocated for years and which are now finding their way into condenser practice.

Inspection of the flow conditions in condenser water-boxes brought out the fact that a quantity of entrained air was present in the circulating water in the condensers. This situation was further developed by the analysis of the circulating water for air content. Series of tests on samples of water taken from various test points on the water-boxes indicated that dissolved as well as entrained air was present in the circulating water, the dissolved air being released as the vacuum increased in the upper sections of the condenser. The air loading of the water was further verified by the installation of glass condenser tubes on typical condensers. Sight glasses at the top of the water-box showed that certain condensers were not entirely filled with water at all times. In such cases the upper rows of tubes would be filled with a mixture of water and air, a large proportion of the mixture being air. Such a combination is ideal for corrosive action, particularly when aggravated by an increase in temperature due to poor heat transfer.

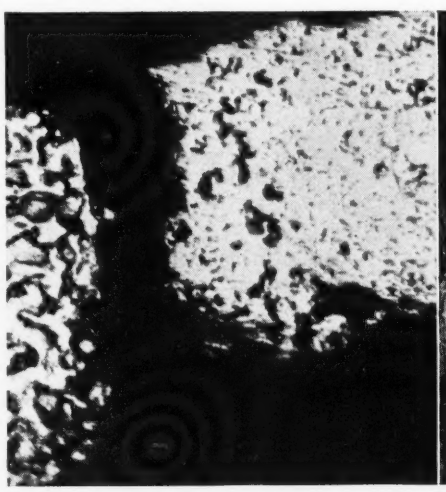
Condensers were found where tube failures were grouped near the top. Examination of these failures showed that they were caused by dezincification and that the dezincification was particularly severe at the top of the tube. This condition could be minimized if the condenser were properly vented so that all tubes would at all times be filled with water.

Although air was considered a corrosive agent, the extent of its action, under conditions of temperature which might be found in the condenser, was not at all certain. Accelerated corrosion tests were made in the laboratory. Comparative tests made with air saturated solutions and solutions under vacuum indicated a marked increase in the corrosion rate due to air. The scope of these labroatory tests will be enlarged to include other corrosive agencies in the circulating water.

Another interesting development of condenser research is the influence of corrosion on a detail of condenser design. In experiments to determine the holding power of "rolled in" tubes, it was found that although full gage tubes have a high holding power, this reduces rapidly as the tube end is thinned. For example: An expanded 1-in. tube had a holding strength of 2,440 lb. Upon reducing the thickness 50 per cent the holding power was reduced to 360 lb. An expanded $\frac{7}{8}$-in. tube had a holding power of 1,460 lb., and on reducing the tube thickness 23 per cent the holding power was 550 lb.

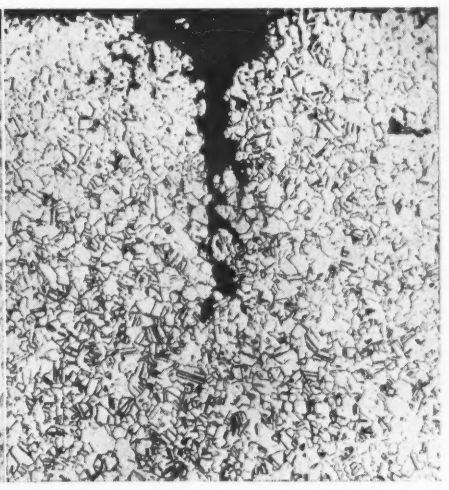
It is clear that in the case of "rolled in" tubes the holding power of the "roll" will rapidly reduce to a point of leakage around the roll as corrosion progresses at the tube end.

The problem of condenser-tube corrosion has been difficult, but definite progress has been made, and it is believed that sound coordinated research intelligently applied will continue to assist in clearing up the unknowns of condenser tube corrosion.



Photomicrograph at point of tube failure showing "plug-type" dezincification

Enlarged photograph showing transverse cracks of over-drawn tube



Photomicrograph showing the crack in a well annealed area

INVESTIGATION OF CORROSION

CORROSION is most often present when the sulphur content of the coal is above 2 per cent. No instances of corrosion were found when the sulphur content was below this value. High-sulphur coal does not always produce corrosion.

THE ZONE of maximum corrosion is usually that immediately in front of the air preheater intake.

CORROSION is most prevalent from high-ash coals and under those conditions of operation in which a large draft is employed, so that a great deal of flue dust is carried by the gas. In many cases where corrosion is severe, trouble is also experienced from the slagging of boiler tubes.

THE HIGHEST metal temperature at which severe corrosion is encountered is about 300 deg. F. Above this temperature the slight corrosion is similar in extent and in type to that which takes place on boiler tubes.

THE CORROSION of preheater tubes is aided by the erosive action of ash particles. It is significant that under the microscope the corroded cross-sectional edges of preheater tubes have a smooth outline, while those of the economizer tubes are rough and pitted.

THE PRESENCE of a zone of high moisture, caused either by a leak or by a steam soot blower, will produce corrosion by gas from almost any type of coal. This localized corrosion takes place in the vicinity of the escaping steam and is distinct from the erosive action of a steam-water jet.

CORROSION in pulverized-fuel systems is never severe, even when the same fuel produces corrosion when fired on a stoker.

DIFFERENCES in the types of construction of economizers and preheaters have shown no great differences in the rate of general corrosion.

PROTECTIVE metallic coatings on the tubes have not withstood the attack. Fig. 2 shows an example of a badly corroded lead-coated tube. Enameled tubes will withstand corrosion if mechanical difficulties in their use can be eliminated.

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AMONG the problems arising from present trends in power-plant design is that of the effect of combustion products on equipment. The simultaneous decrease in exit-gas temperatures and the increase in the sulphur content of the coal, as well as a change in the character of the ash, have produced a condition favorable to corrosion. As a result of these modifications, the deterioration in the economizers and preheaters, especially at temperatures where the metal may exist below the dew point of the gases, is quite severe. The use of higher operating pressures has also entered into the development of the problem, because of the greater prevalence of leaks, a condition that is favorable to rapid corrosion. In some cases the corrosion has been so severe that the life of a preheater tube is not greater than one year and failures in the colder section of the economizer have taken place in as short a time as three months.

To determine definitely what factors present in the furnace gas may be regarded as controlling the rate of corrosion a survey was made of several power stations in various sections of the United States. Included in this investigation were both those plants experiencing corrosion from the combustion products and those that have been practically free from this trouble. In many cases plants were visited and the economizers and preheaters closely inspected for localized and general corrosion. Conditions of operation and characteristics of design were ascertained. In all cases data were fur-

Fig. 1—Development of a leak in a rolled joint

BY FLUE GAS

By H. F. JOHNSTONE
Special Research Associate
University of Illinois

nished by the operating staffs that were useful in summarizing the conditions causing corrosion. The results of this survey made by the Univ. of Illinois cooperating with the Utilities Research Commission permit of the general statements made on the opposite page.

It became apparent in making the survey of power plants that two types of corrosion are present as a result of conditions in the flue gas. First, there is a localized corrosion that is confined mostly to the ends of the economizer tubes, and, second, there is a general corrosion which covers the entire tube surface in the colder part of the economizer and in the preheater. Fig. 3 shows the severity of this attack in the economizer and Fig. 4 that in the preheater.

Local corrosion is caused by the high moisture content of gas in the immediate vicinity of a leak. Of the two, this type of corrosion has proved the more severe. Many of these leaks were due to failure of the rolled-type of economizer construction to withstand the high pressures used in modern boilers. Although this cannot be entirely explained at present, the development of leaks through rolled joints is possibly due to the expansion and contraction of the tubes with temperature changes, combined with some chemical action.

In many cases the water escaping under high pressure has cut channels like worm holes along the surface of the joint. The development of such a leak is illustrated in Fig. 1. Evidently, therefore, a joint made absolutely water-tight at the beginning will stand less chance of developing a leak after it has been in service than one that originally showed seepage. A trace of water in the joint itself is sufficient to cause a slight corrosion, which decreases the resistance to the passage of water. A small jet of water soon escapes, and the high pressure erodes the opening until it is sufficient for a large leak. Unfortunately, a leak not only damages the tube from which it originates, but also affects all those in its immediate vicinity. A part of the damage is caused by erosion by the direct water-steam jet and a part is caused by the corrosion resulting from the excess moisture. The latter is particularly bad in the presence of a scale deposited from the flue dust. The character of this scale depends somewhat on the type of coal burned and on the methods of operation; so that the local corrosion has been more severe in some plants than in others; but few plants have escaped the loss of some tubes due to corrosion originating from leaks. New designs in economizer construction in the last few years fortunately make it possible to place all joints where leaks might occur entirely outside the gas passage. Although the leaks themselves have not been eliminated entirely, the conditions set up by them have been removed and the local corrosion has disappeared in plants using this type of construction.

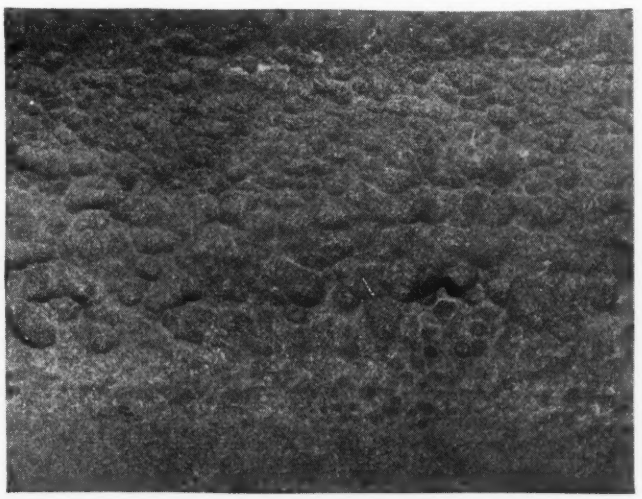

Fig. 2—Corroded lead-coated economizer tube

A change in the type of corrosion reaction occurs when the flue-gas temperature is lowered to a point where a liquid film is formed on the metal surface. At higher temperatures there may be a slight oxidation such as exists on the surface of boiler tubes. Below the so-called dew point, not only will a film of acid be present, but other corroding agents will be brought into solution.

Various estimates of the dew point of flue gas have been made. Unfortunately, most writers have not realized that a trace of sulphuric acid vapor in the gas materially affects the temperature at which liquid will form. Estimates of the dew point based on the percentage of water vapor in the gas show that liquid will first appear between 90 and 100 deg. F. It can be shown by calculation based on the partial pressures of sulphuric acid and water over acids of high concentrations that this temperature is 20 to 100 deg. F. too low, depending upon the concentration of acid vapor in the gas. Furthermore,

the liquid condensing at these high temperatures contains 70 to 90 per cent sulphuric acid. Because of the importance of the dew point in the corrosion investigation these calculations were verified by direct determination of the dew point by an electrical method. This of course did not make use of the familiar wet- and dry-bulb principle, but depended upon the change in electrical conductivity of a glass surface at the dew point.[1]

Fig. 5 shows the fluctuations in the dew point with rate of evaporation from a furnace burning high-sulphur Illinois coal. A thorough study of the flue gas at this plant showed the average composition to be: CO_2, 10.7 per cent; SO_2, 0.279 per cent; SO_3, 0.0082 per cent.

Although the dew point as determined by this method is the actual condensation point of pure flue gas and exceeds that based on the water vapor content of the gas, actually a moist film can exist even at temperatures above the dew point. This is possible when the deposits of flue-dust contain hydroscopic substances, that is, substances that become moist because their saturated solutions have lower vapor pressures than that of the water and sulphuric acid in the surrounding gas. Since sulphates of iron, which often constitute as much as 40 per cent of these deposits, are known to absorb moisture readily, corrosion can be expected at still higher temperatures when this condition exists.

A further study of the causes of the corrosion showed these sulphates of iron take other important parts in the reactions. It was definitely determined that the greatest part of the oxidation of the sulphur dioxide in the flue gas takes place in these moist films containing solutions of iron salts. The product of this oxidation is sulphuric acid. On the other hand, a thorough study of the sulphur compounds in the gas showed scarcely any oxidation in the gas and also that the slag and hot dust particles do not act as catalysts for the oxidation.

When soluble iron salts exist in the dust deposits they form concentrated solutions below the dew point of the gas. These solutions are very corrosive, because of the oxidizing action of the ferric ions. In fact, this action is more severe than that of sulphuric acid solutions. The action is of a galvanic nature, there being an exchange of electrical charges between the metallic iron and the ferric ions.

[1]A description of the apparatus and results was published as Circular No. 20 of the University of Illinois Engineering Experiment Station.

Fig. 3—General corrosion of economizer tube

The relation of the dust composition to the rate of corrosion, therefore, is quite apparent. Although the effect of type of fuel burned and method of firing on the character of the flue dust was not fully investigated, nevertheless the following preliminary statements are justified by the data obtained:

1. Soluble iron-sulphur compounds in flue dusts are the result of incomplete combustion of the pyrites in coal. When coal is fired as powdered fuel the more complete oxidation removes the sulphur from the dust and converts the iron into insoluble silicates.

2. There is a selective adherence to these unoxidized or partly oxidized particles of pyrites to tubes and walls. The oxidation is completed after the particles separate out to yield, at high temperatures in the boiler proper, iron oxide and sulphur dioxide and, at lower temperatures in the economizers and preheaters, iron sulphate. The incomplete combustion of pyrites, therefore, may be considered at least partly responsible for slag formation and almost entirely responsible for adherent deposits in economizers and preheaters.

The minimum temperature at which economizers and preheaters may be operated without danger of corrosion varies from plant to plant. With a coal containing 1 to 2 per cent sulphur that burns readily without requiring a large draft no corrosion should be encountered if the metal temperature is maintained above 150 deg. On the other hand, high-sulphur coals that require a large draft and wetting down with water to hold on the grate will cause corrosion at temperatures up to 300 to 325 deg. It should be pointed out that it is the surface temperature of the metal that is of importance and not that of the gases, water or air. In economizers the metal temperature runs about 10 deg. above the temperature of the entering water at the cold end and about 40 deg. above that of the exit water at the hot end. These values represent temperature differences for clean metal surfaces. When dust deposits cover the surface the temperature is closer to that of the water.

The surface temperature of clean preheater tubes is approximately the mean temperature of the gas and air at the cold end and about 20 deg. nearer the temperature of the air than that of the gas at the hot end. In a preheater the effect of dust deposits is especially noticeable, and the metal temperature is much lower under this condition. It is possible, therefore, that while a clean preheater may be operated entirely above the condensa-

tion temperature of the gas, condensation and corrosion will take place when dust collects in corners of the structure.

In the design of preheaters care should be taken to get good circulation of flue gas in all parts so as to prevent the collection of dust and to secure a uniform temperature gradient. This is particularly true in the plate type of preheater, where the corners are likely to be out of the main gas stream. Because of the difficulties in cleaning the plate-type preheater, a non-uniform flow of gas is often the cause of severe corrosion. Tubular preheaters also become partly clogged in spite of a fairly uniform flow of gas. Corrosion is always severe in the clogged tubes. Even when petroleum residues are burned, clogging of the preheater can take place. This may be produced by certain combinations of fuels which give an undesirable type of ash, or even by the product of corrosion when the action is severe. In general the most severe corrosion takes place in front of the air intake. Use of recirculated hot air or of the parallel flow principle to raise the metal temperature will overcome this difficulty. Either of these, of course, will decrease the capacity of the preheater.

The greatest step that can be taken to eliminate the local corrosion that exists in more or less severity in all plants is the elimination of leaks in the economizers. This applies particularly to leaks around tube ends.

Under certain conditions a reduction in corrosion by any of the changes outlined above is obviously impossible. For instance, the corrosion of fan blades may be difficult to control under any condition. Also the economic loss involved in maintaining a high minimum preheater metal temperature may be such that the change is not warranted for some types of fuels. In such cases the obvious solution is the use of non-corroding alloys that will withstand the action of the corrosive conditions. Although the original cost of the alloy is somewhat higher than that of steel, the greater life and dependability will often more than compensate the original investment.

In connection with this investigation some 56 alloys of various compositions, 16 paints and several enamel coatings were tested for their corrosion resistance. These tests were made in four ways: (*a*) an accelerated test in which the samples were immersed in aërated solutions of 36 and 50 per cent sulphuric acid at 200 deg. F., (*b*) an accelerated test in aërated solutions of 36 and 50 per cent sulphuric acid saturated with ferric sulphate at 200 deg. F., (*c*) a slow test in which the samples were suspended in flue gas (from the combustion of coal gas) of constant composition, to which was added sulphur

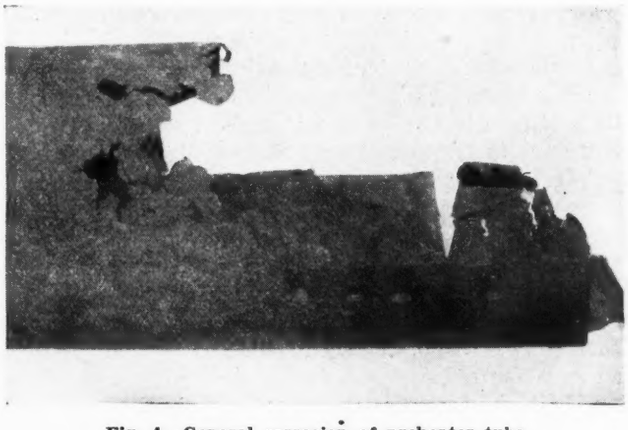

Fig. 4—General corrosion of preheater tube

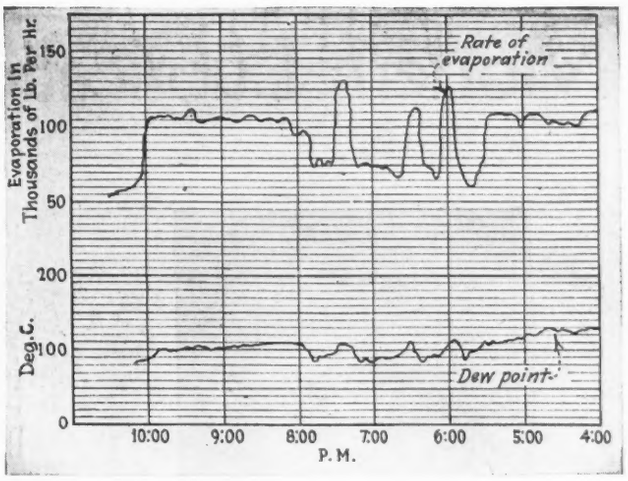

Fig. 5—Fluctuation of dew point and evaporation-high sulphur coal

dioxide gas and sulphuric acid vapor, maintained at 200 deg. F., and (*d*) samples covered with solid ferric sulphate exposed to the same gases as (*c*). The results of these tests may be summarized as follows:

1. The corrosion of pure iron is greatly accelerated by the presence of ferric sulphate.

2. The presence of small amounts of copper, nickel, molybdenum, silicon, carbon, manganese, phosphorus or sulphur in iron or steel does not noticeably affect the rate of corrosion by flue gas.

3. Chromium steels are attacked rapidly by pure acid, but in the presence of ferric sulphate they are rendered entirely passive and corrosion is not noticeable. The maximum protection is afforded by the presence of between 14 and 30 per cent chromium in the steel.

4. The addition of nickel to chromium steels does not decrease the corrosion resistance until more than 20 per cent has been added. The type of alloy known as "18-8 stainless iron" offers excellent resistance to flue gas.

5. Copper alloys, in general, are rapidly attacked by the action of ferric sulphate, the corrosion being several times that produced by pure sulphuric acid. It was interesting to note that copper-steel was no more resistant to the conditions than ordinary steel.

6. Chemical lead and antimonial lead are attacked by the action of flue gas at 200 deg. F. This emphasizes the fact that the concentration of sulphuric acid condensing from the gases at this temperature is high.

7. No paints were found that were absolutely resistant to the hot gases. A few of the artificial phenol resins seemed to provide good protection.

From these results the chromium alloys are at present the best protection against corrosion by flue gas at temperatures below the dew point. Because of the cost of these it will usually be found expedient to operate above the dew point even with the sacrifice of a small percentage of efficiency. It is to be hoped that developments in the future will lead to a more satisfactory preparation of the fuel, with the elimination of greater proportions of the sulphur and ash.

The author wishes to express his appreciation to Prof. D. B. Keys, in charge of research in chemical engineering at the University of Illinois, for his interest and suggestions concerning the work.

This article is published by permission of the director of the Engineering Experiment Station, University of Illinois. The complete results of the investigation will be published as Bulletin No. 228 of the Experiment Station.

Modern Lubrication Studies

An Interview With

ALAN E. FLOWERS

Modern high-speed heavy-duty power machinery is so dependent upon lubrication that almost every user is confronted with problems involving the maintenance of journal oil film. Mr. Flowers is lubrication specialist, De Laval Separator Company, and chairman of the A.S.M.E. Special Research Committee on Lubrication.

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WHILE lubrication has been a necessity since the first crude cart creaked its way along the trail, until recent times, the theory and application of lubrication to rotating and sliding machine parts has been in the main by rule-of-thumb methods, most of which have been proved in error through subsequent researches.

The effect of pressure upon the viscosity of a lubricant has always been a disputed point. Work done by several independent investigators covers a large number of oils. While no conclusive proof has yet been presented of the solidification of castor oil or a pure asphalt-base oil, several tests reveal that other lubricants do solidify under high pressure, ranging from sperm oil, which solidifies at a pressure of 11,000 lb. per square inch, to a mineral oil which becomes non-fluid at 92,000 lb. and a temperature of 167 deg. F.

A simple confirmation of the increase in viscosity at high pressure was obtained by forcing oil through a long capillary tube, with a high inlet pressure. It was found that beyond a certain pressure the flow did not increase with a further rise in pressure, indicating that the viscosity had changed substantially.

One factor remaining undetermined is the cause of oiliness, that is, the ability of some oils to reduce the frictional resistance of a journal in a bearing when all other known and measurable conditions are made the same. While tests have revealed the comparative oiliness of various oils, the cause of the variation is unknown so far, although the behavior of an oil can be predicted with some certainty.

The term "oiliness" has been in use for years without any standard definition agreeable to all. At present that of W. H. Hershell is commonly accepted, namely that oiliness is that property which causes a difference in friction when two or more lubricants are tested under identical conditions, the lubricants having the same viscosity at atmospheric pressure and at the same temperature as the actual oil film.

In tests conducted at Carnegie Institute of Technology it was found that, although the design of the apparatus eliminated all influence of viscosity there was a wide divergence in the behavior of the lubricants tested, showing that there was some special property in oil which exercised its own influence on friction. As the experienced lubrication engineer would expect, the mineral oils had less oiliness than had some of the fatty oils.

Probably the most important phase of lubrication is that of journal bearings. At the present time the unit loadings of bearings are by no means based on scientific reasoning. In fact, the relations of loading, journal speed, kind of lubricant and bearing temperature have not been completely established.

To explore the pressure distribution of the oil film in a bearing the Bureau of Standards has constructed an apparatus by which the pressure at all points of the bearing may be found. Observations on this machine do not conform exactly to the Sommerfield pressure-distribution curves obtained by calculation under certain assumed conditions. It is now proposed to investigate commercial bearings to discover the point at which lubricants change from the stable to unstable state. In "running in" bearings, using the same load capacities, it was found that the bearing metal containing the greater lead percentage could be "run in" at the expenditure of less power.

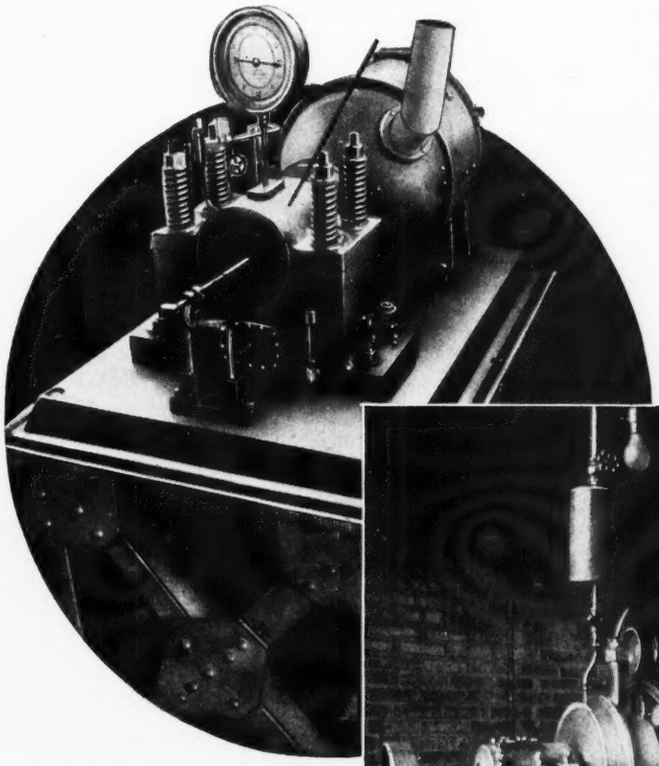
In the development of theoretical formulas for pressures in bearings, the equations indicate that there should be a large negative pressure at the low-pressure area. Recent tests at Pennsylvania State College indicate that this is by no means true under normal working conditions. These tests include measurements of the total pressure on a bearing and the pressures at different angular positions, and cover a range of pressures considerably greater than that found in modern practice.

Investigations by Ronald Bulkley at the Bureau of Standards reveal that at a film thickness of a millionth of an inch the ordinary laws of motion of viscous fluids could be relied upon. The so-called "clogging" of capillary tubes, reported by Wilson and Barnard, were found

by Bulkley to be due solely to foreign substances in the liquids tested.

Tests by engineers of the Sinclair Refining Company indicate that petroleum oils vary in film strength from 3,000 to 12,000 lb. per square inch before seizure occurs. Furthermore, oils of the same viscosity but from different crudes have different film strengths. Dewaxing the oil to zero degree pour point raises the film strength, and by adding 5 per cent of fatty oils, the strength of a petroleum oil is raised about 5 per cent. The same investigators found that the film strength of crankcase oil decreases as the oil decomposes from oxidation and carbonization.

Hydrogenation has been seized upon as affording a means of obtaining a suitable oil from an inferior crude, through the addition of enough hydrogen atoms to give the hydrocarbon molecular structure that may be needed. But until more is definitely known concerning the influence of the molecular structure, no great headway may be expected.



Machine employed by the Navy in testing the value of bearing oils submitted by bidders on Navy lubrication contracts

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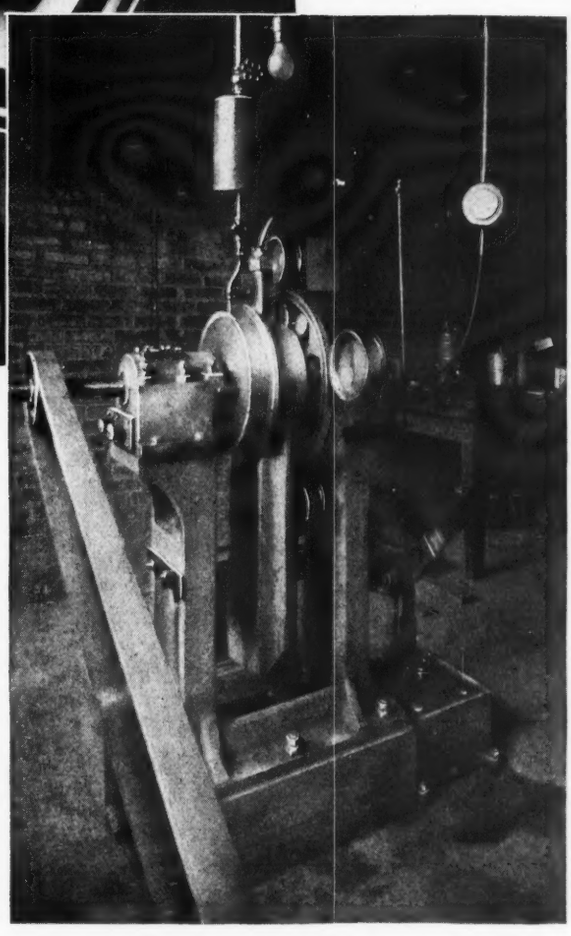


Test machine used at Pennsylvania State College in the bearing lubrication research conducted under The Texas Company fellowship

The advent of reciprocating engines employing high-pressure and high-temperature steam has brought with it a difficult lubrication problem. Although a cylinder oil with a burning point of over 800 deg. is not impossible, there is always the danger that such oils may proceed to break down under these high temperatures. As yet the problem cannot be said to have been entirely surmounted.

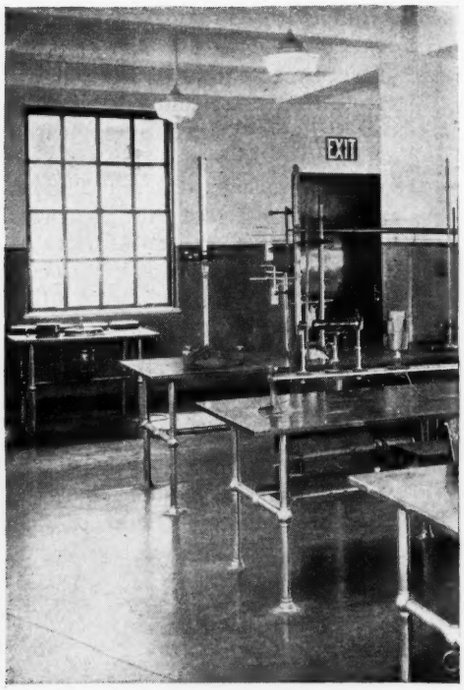
Clarification of condensate from such engines has, through research activities, been made possible both by cloth filtration and by centrifugal methods. In the latter the mixture is passed through a centrifuge, which removes the oil, leaving the water with not over 0.003 per cent of oil in it. For that matter, it has never been proved that oil in boiler feed will injure a boiler if the latter be properly designed.

Internal-combustion engines consume, by far, more lubricating oil than any other type of mechanism. Investigation has been and is still being conducted on the recovery of crankcase oil from automobiles. The oil carries considerable carbon and metallic particles, but tests indicate that the oil after proper treatment is equal, if not superior, to a new oil. A new oil suffers some deterioration soon after it is introduced into the engine. The removal of the deteriorated products leaves a more stable reclaimed oil, with equal, or even better lubricating properties. Metallic particles and dirt are readily removable, leaving the oil practically unchanged. Gasoline dilution may be removed by heat, or by distillation, but unless unusually high may be allowed to remain, since it represents an automatic self-adjustment of engine and oil to the actual conditions of service. The danger, if any, lies in any attempt to use reclaimed oil from one type of engine in another type.

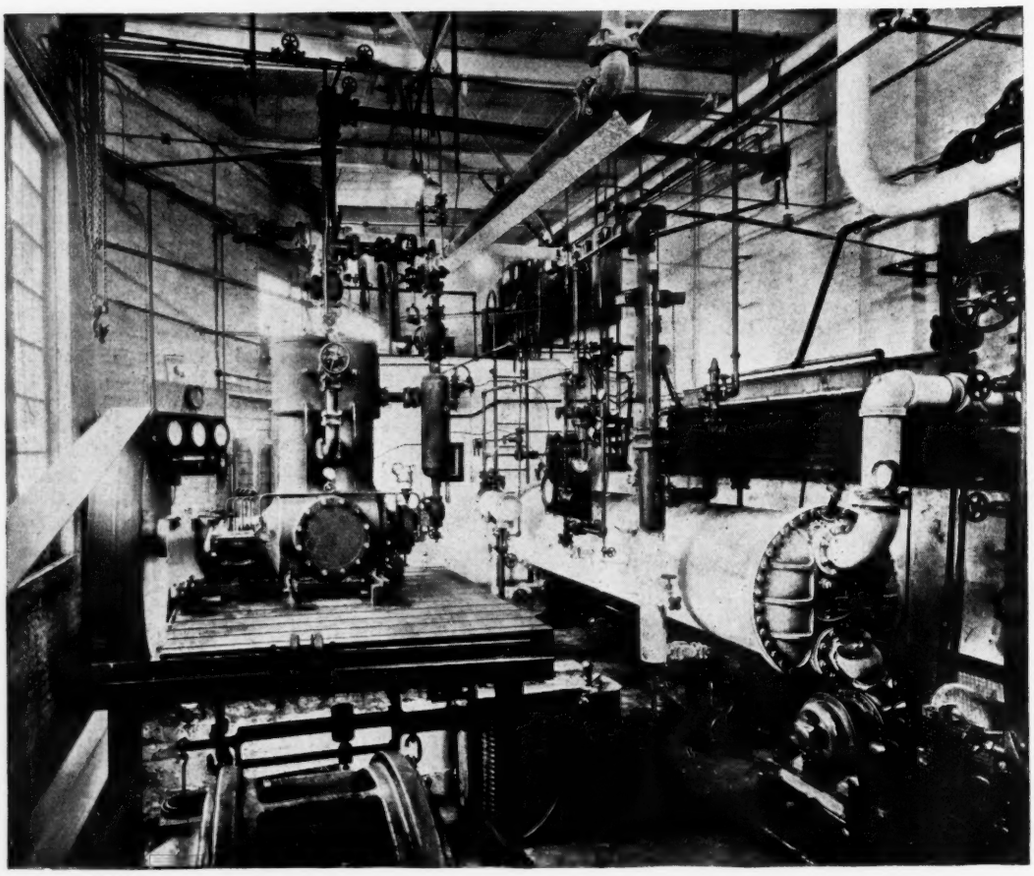
Long tests have been made on the contamination of diesel engine crankcase oil, with the result that most of the deterioration has been found to be due to sand, dirt and metallic particles, with little actual oxidation of the oil itself, although "cracking" appears to be present to some extent.

In any circulating system, and especially in turbine oiling systems, acid conditions have been found in the oil after a short period of use. These result from oxidation, and as they are more soluble in water than in oil, a thorough washing of the oil with water prior to centrifugal purifications is becoming a common practice, using hot water in order to take advantage of the greater solubility of these acidic bodies at higher temperatures. This process prolongs the life of an oil charge almost indefinitely and is becoming the accepted method.

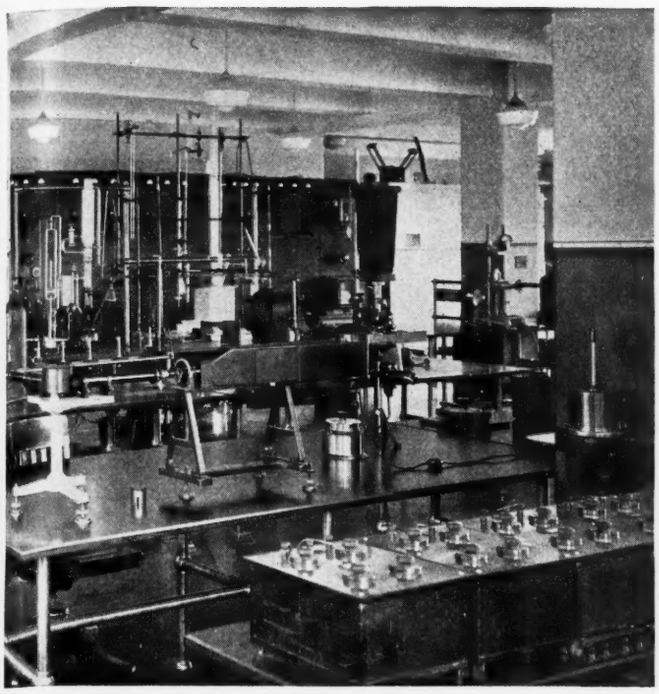
Power Progress
IN THE MAKING



Experimental set-up of Nicholls heat flow meter to study meter characteristics and flow of heat through roof at A.S.H.V.E. laboratory, U. S. Bureau of Mines, Pittsburgh

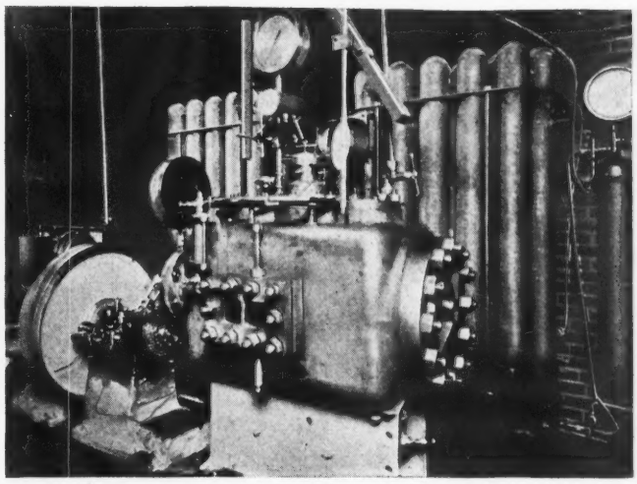


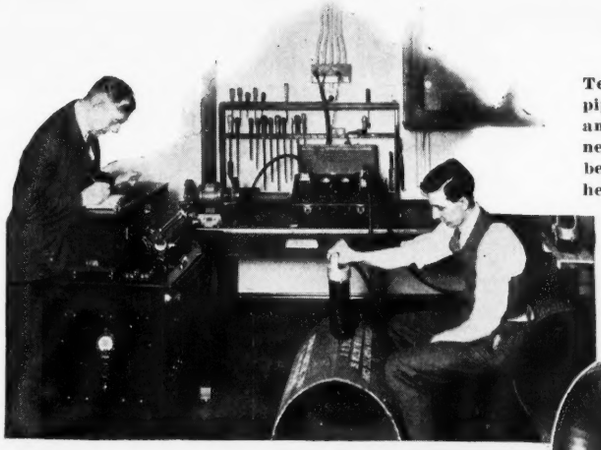
A recently developed vertical enclosed type ammonia compressor of the multiple-effect design being tested in the manufacturer's development laboratory to determine its performance at various suction pressures



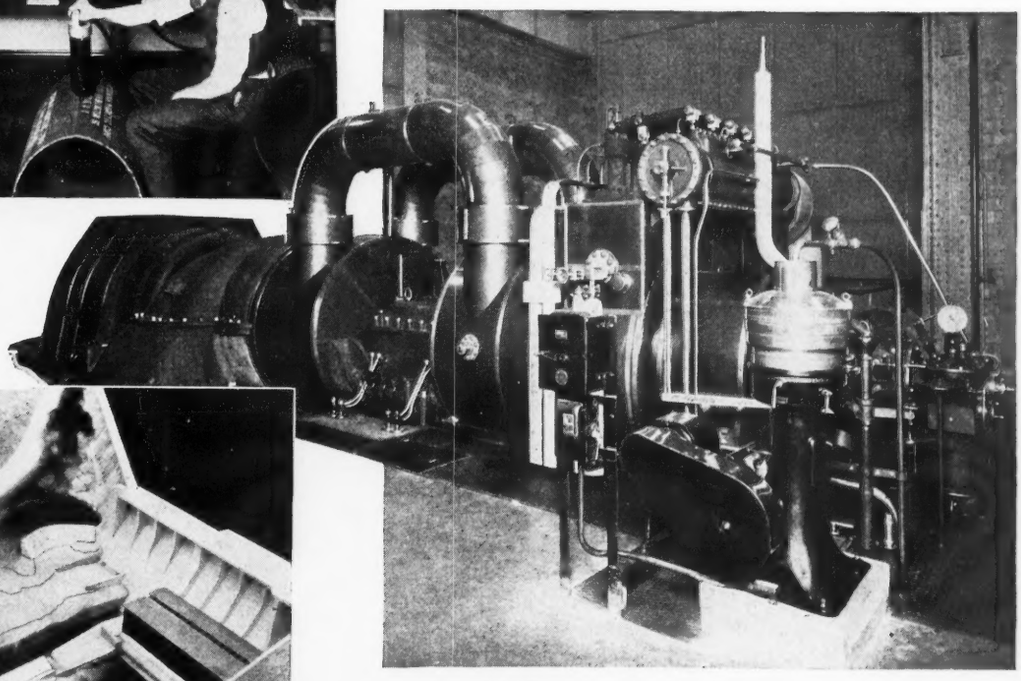
A corner of the research laboratory of the Brooklyn Edison Co. showing electrical testing equipment and switchboard control panel

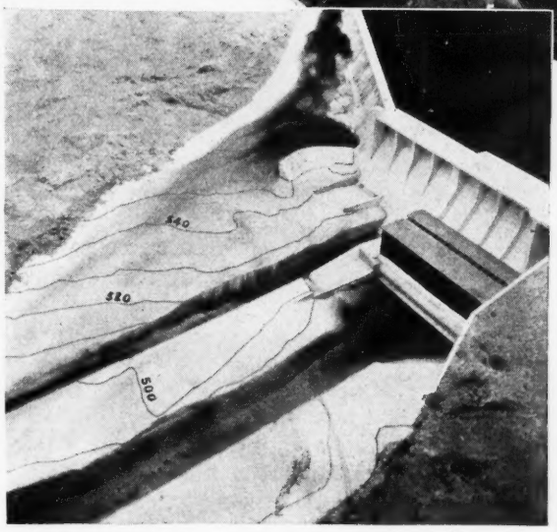
Pressure chamber at Pennsylvania State College for studying diesel fuel spray characteristics. The chamber has heavy glass windows for visual observation





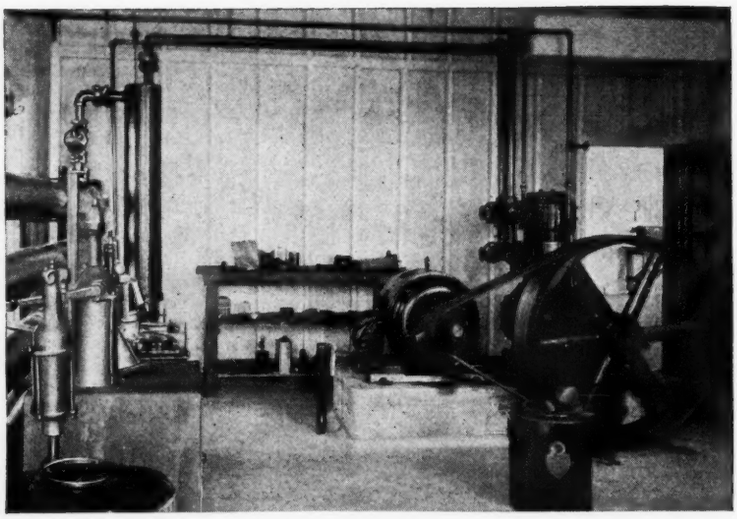
Testing a section of welded pipe with magnetic tester and oscillograph. One magnet is moved along the weld being tested and the other held stationary on a standard





Model of the 200,000-hp. Fifteen Mile Falls hydro project of the New England Power Association built and tested in the Alden Hydraulic laboratory of the Worcester Polytechnic Institute

The 10,000-kw. experimental 1,000 deg. turbine at the new Delray Station of the Detroit Edison Co. With this unit it is expected much will be learned about the operation and performance of high temperature equipment



One of the outstanding developments in refrigeration application is quick freezing of food. The illustration shows an experimental plant engaged in freezing fresh fish by this method

REFRIGERATION DEVELOPMENT Makes NEW INDUSTRIES

Studies in refrigerating media, metallurgy and heat-transfer of refrigeration equipment have permitted the technical advances in old industries and the creation of new industries

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THE LOW temperatures and pressures carried by refrigeration systems have enabled the designer and maker of such equipment to avoid the metallurgical problems which are so serious in the steam-engineering industry. Consequently, although some minor studies have been made of new metals, most of the refrigerating research has been centered about the properties of the old and new refrigerants, heat transfer in condensers and evaporators, influence of evaporator design and the application of refrigeration.

Encouraged by the universal acclaim over the complete tables of the properties of ammonia which the Bureau of Standards compiled after a long series of tests, the government physicists and the membership of the American Society of Refrigerating Engineers proceeded with the work preliminary to the preparation of tables on carbon dioxide and carbon bisulphide. Some funds have been obtained from manufacturers of refrigerating equipment and supplies, and the work is proceeding as rapidly as should be expected. It will be some time, however, before the tables are completed. More rapid progress could be made if more funds were available, as at present the work cannot proceed uninterruptedly. Certainly this activity deserves the support of every one engaged in the several phases of refrigeration. Especially is there a need for accurate carbon-bisulphide tables, since that refrigerant has possibilities in household machines. In the meantime the industry has a choice of several more or less inaccurate tables.

Extended employment of refrigeration in industrial processes has led to research into better methods and principles of automatic control of temperatures. Frequently it is necessary to place a refrigerating unit in a factory where personal attendance is impossible because of expense. As a result of several studies, automatic control of large machines is becoming as possible as the control of household refrigerators.

Probably more investigations are being carried on concerning the influence of process temperature control through the application of refrigeration than on any other phase of the subject. As a result of these studies it has been found that refrigeration permits the speeding up of many manufacturing processes, and at the same time maintaining, if not improving, the product.

Refrigeration of fruit, vegetables and meats while in transit has occupied the attention of many. Several of these research prospects have resulted in the development of interesting new cooling methods, so that it is only a question of time until rail cars will be equipped with individual refrigerating plants, adsorption system and frozen carbon dioxide.

Better and cheaper methods of obtaining the CO_2 gas from which the solid carbon dioxide is manufactured are engaging the attention of several laboratories.

After a long interval of investigation, refrigeration now is being applied to home cooling as well as to office buildings and theaters. If present research is productive of the expected results the factory of the future may be completely sealed, with its temperature maintained at the efficiency value during the entire year.

The small domestic refrigerating machine has been the subject of more laboratory work than the larger commercial units. Heat-transfer rates have been determined and better boxes have resulted. The efficiency of the small compressor has been given a better performance and the control instruments made more serviceable.

Future research will include a study of the best methods of holding goods in cold storage as regards temperature, humidity, fresh air and CO_2 content. More exact information should be obtained in regard to the advantage of very low temperatures. Better information is needed on the properties of the refrigerants, including SO_2, CO_2, and perhaps methyl chloride. Heat transfer enters into refrigeration to such an extent that it is vital that more information should be secured along this line, and the flow of fluids should be studied more with an idea of securing a rational formula or diagram.

Current Research in Power and Allied Fields

THE RESEARCH projects in the following tabulation represent work in progress or completed during 1929, 1930 or 1931. Many of the projects were obtained from replies to inquiries sent to over 130 universities and colleges equipped with research laboratories. Valuable assistance was also rendered by the U.S. Bureau of Mines, the Bureau of Standards and other governmental agencies. The research work of the power utilities was obtained from the National Electric Light Association, which organization had recently made a survey of the investigations undertaken by its member companies; individual companies also cooperated. Additional assistance was obtained from the various engineering societies and research organizations, and many manufacturers of power equipment were canvassed. Researches in progress outside of the United States were obtained from several sources including the engineering societies in the various countries.

This survey clearly indicates the vast variety of investigations that have been undertaken. The table contains over 600 items of research, which have been broadly classified under the following headings or sub-divisions: boilers, combustion, condensers, corrosion, electrical, feed water, fluid flow, fuels, heat transfer, heating and ventilating, internal combustion, lubrication, materials, smoke and dust abatement, steam prime movers, thermal, water power and welding.

Every effort has been made to include only those researches that would be of interest to power engineers. For example, under materials might have been included a vast amount of metallurgical research, but only items such as the properties of steel at elevated temperatures have been selected. Similarly, under welding, researches that have to do with the properties of welds and methods of testing have been included, but researches concerning welding methods and technique have been omitted.

POWER wishes to thank all whose hearty co-operation has made possible this compilation of power researches.

BOILERS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation of circulation in boiler furnace water walls.	Yale U.	Yale U.	In progress.	
Entrainment of solids in steam.	Commonwealth Edison Co.	Commonwealth Edison Co.	In progress.	Present work has as its objective the factors in boiler operation affecting carryover.
Carryover characteristics of cross-drum boiler at high rating.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Investigation of cause of failures of boiler tubes.	Detroit Edison Co. and U. of Michigan.	Detroit Edison Co.		
Study of the economic distribution of heating surface between water walls, convection surface, economizer, and air preheater.	Johns Hopkins U.; Warren Viessman.	A. G. Christie.	In progress.	
Study of high-pressure steam with a special boiler designed for a pressure of 3,500 lb. and temperature of 830 deg. F.	Purdue U. Mech. Eng. Lab.; A. A. Potter, G. A. Young, H. L. Solberg.	Purdue U. Eng. Exp. Sta. co-op. with the B. & W. Co. and power utilities.		Projected boiler will be installed during the spring of 1931.
Removal of slag in lower tube bank of a boiler by means of steam blowers.	Commonwealth Edison Co.	Commonwealth Edison Co.; investigation being carried on in conjunction with manufacturer.	In progress.	Results indicate steam and water mixing is effective but maintenance cost of elements is high.
Comparative tests of steam purifiers.	Rochester Gas & Elec. Co.	Rochester Gas & Elec. Co.	N. E. L. A. Prime Mover Report on Boilers' Superheaters and Economizers, Aug., 1930.	
Investigation of steam generators at pressures of 1,500 to 3,500 lbs.	Babcock & Wilcox Co.	Babcock & Wilcox Co.	In progress.	
Investigating superheating of steam to 1,100 deg. F.	Babcock & Wilcox Co.	Babcock & Wilcox Co.	In progress.	
Research on Benson boiler.	Eng. lab., Technical U., Charlottenburg, Berlin; Prof. Josse.		Trans. V.D.I. 1929; completed 1929.	
Water-wall research, including investigation of flow through circulating tubes.	American Eng. Co.	American Eng. Co.	In progress.	Resulted in development of water wall suitable for stoker installations.
Experimental study of circulation in vertical water tube boilers.	Germany; E. Schmidt and P. Behringer.		Completed 1929.	Studies and measurements were made to determine the circulation force, the rates of heat transfer in the tubes, the density of the steam and water mixture, and the relative velocity of steam bubbles to that of the circulating water.
Experiments to determine influence of external conditions on the rate of vaporization of water and other fluids.	Germany; E. Schmidt and R. Hilpert.		In progress.	
Relation between steam pressure and evaporation in high-pressure water-tube boiler.	Locomotive Mfg. Co., Japan; T. Ikegi.	Locomotive Mfg. Co.	In progress.	
Influence of boiler scale on the efficiency of boilers.	Kiryu Tech. College, Japan; Y. Oyama.	Kiryu Tech. College.	In progress.	
Heat-preserving effect of double tube.	Tech. College, Tokyo Imp. U., Japan; S. Nukiyama.	Tokyo Imp. U.	In progress.	
Model boiler test.	Tech. Res. Inst. I.J.N., Japan; Y. Katsura.	Imperial Japanese Navy.	In progress.	

COMBUSTION

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Performance of different kinds of coal in furnaces from which ash is removed in liquid form.	Pennsylvania-Ohio Power & Light Co.	Co-op. with U. S. Bureau of Mines.		
Study of the burning of fuels in a furnace wherein pressure is maintained at about 7 atm.	Oregon State Agr. College, Mech. Eng. Dept.; Prof. F. G. Baender.	Oregon State Agr. College.	In progress.	It appears that it may be possible to develop approximately 1,000 per cent rating.
Investigation of possible hydrocarbon stack loss.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Study of improvement in operation of stoker-fired boilers by changing relation of forced and induced draft.	Hudson Ave. station	N. Y. Edison system.	Completed 1930.	Material improvement effected.
Effect of introducing overfire air over each retort of underfeed stoker.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Combustion tests with Illinois coal.	U. of Illinois Eng. Exp. Sta.; A. P. Kratz.	Zeigler Coal & Coke Co.	Bul. 213 U. of Ill. Eng. Exp. Sta.; completed.	
Smokeless combustion of bituminous coal in heating boilers.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; P. Nicholls.	U. S. Bureau of Mines.	U. S. Bureau of Mines Report of Investigations 2943, 1929; H.P.A.C., Vol. 5, 1929, pp. 423-427.; completed 1929.	
Behavior of different coal dusts as regards propagation of flame.	U. S. Bureau of Mines Exp. Mine; G. S. Rice, H. P. Greenwald.	U. S. Bureau of Mines.	U. S. Bureau of Mines Tech. Paper 464, 1929; in progress.	
Inflammability of coal dust.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; H. P. Greenwald.	U. S. Bureau of Mines.	Many publications; in progress	
Study of the process of combustion of pulverized coal.	Battelle Memorial Inst.; R. A. Sherman.	Battelle Memorial Inst.	In progress.	A complete plant for the preparation of pulverized coal is installed, together with a furnace in which the coal is burned and the progress of combustion studied. The effects of coal fineness, type of coal and amount of excess air are now being investigated.
The burning of individual particles of pulverized fuels.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; B. Lewis.	U. S. Bureau of Mines and Carnegie Inst. of Tech.	Ind. & Eng. Chem. Vol. 21, No. 9, 1929, pp. 808-815; in progress.	
Effect of preheated air on fuel-bed characteristics.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; P. Nicholls.	U. S. Bureau of Mines.	In progress.	
Fundamental processes of gaseous combustion.	Peoples Gas Light & Coke Co.; R. B. Hooper.	Utility Research Comm.	In progress.	
Studies of pulverized coal in marine boilers.	Mason Lab. Yale U.; Prof. H. L. Seward.	Mason Lab. Yale U.	In progress.	
Studies of combustion process in power boiler furnaces.	Mason Lab. Yale U.; Prof. W. J. Wohlenberg.	Mason Lab. Yale U.	In progress.	
Study of causes of spontaneous combustion of stored coals.	Purdue U.	Eng. Exp. Sta. Purdue U.	In progress.	
Investigation of ignition and combustion in the powdered-fuel engine.	Dusseldorf, Germany; Ing. Wentzel.		Completed 1931.	
Investigation of problems in handling and burning coal.	Harvard U.; C. H. Berry.	Large industrial corp	In progress.	
Combustion of pulverized lignite.	U. of North Dakota, Grand Forks; R. L. Sutherland.	U. of North Dakota.	In progress.	
Spontaneous combustion of lignite.	U. of North Dakota, Grand Forks; A. W. Gauger, George A. Brade.	U. of North Dakota.	In progress.	
Temperature tests of boiler furnaces and fusion of ash.	U. of Michigan power house, U. of Mich.; G. G. Brown.	U. of Michigan.	In progress.	The temperatures in the firebox were found to be well above the fusion points of the ash from the coals being used.
The mechanism of combustion of coal in suspension.	Fuel Engineering Co.	Fuel Engineering Co.	In progress.	
Investigation of factors influencing removal of ash as molten slag from furnaces burning pulverized coal.	Pennsylvania-Ohio Power & Light, Toronto sta.	Stevens & Wood, Inc., and U. S. Bureau of Mines.	A.S.M.E. Trans., Vol. 51, No. 22, 1929.	
Pulverized-coal experiments.	H. C. Porter, Philadelphia.	H. C. Porter.		
Experiments on radiation, heat absorption and progress of combustion.	Detroit Edison Co., Detroit.	Co-op. research Yale U., Detroit Edison Co., Superheater Co.	In progress.	
Performance studies of a stoker-boiler unit, to determine operating characteristics and best method of stoker control for heating service.	U. of Illinois; Prof. A. C. Willard.	U. of Illinois Mech. Eng. Dept. and Eng. Exp. Sta.	Work is in preliminary stage.	
Study of Indiana coals on small stokers.	Purdue U.; A. A. Potter.	Purdue U. Exp. Sta.	In progress.	
Study of small stokers utilizing Indiana coal.	Purdue U. Eng. Exp. Sta.; G. A. Young.	Indiana Coal Trade Assn.	In progress.	Tests have been completed on five different types of small stokers using seven different kinds of Indiana coal from four veins. Additional tests are in progress and the results will be published in bulletin of Purdue Eng. Exp. Sta.
Performance of oil burners on various types of boilers and furnaces.	Yale U.; L. E. Seeley.	A.S.H.V.E. and Am. Oil Burner Assn.	In progress.	
Furnace-gas compositions and temperatures in underfeed stoker-fired boilers and their effect on boiler settings.	Connors Creek Plant of Detroit Edison Co.; A. C. Pasini, E. M. Sarrof.	Detroit Edison Co.	A.S.M.E., Dec., 1930.	
Investigation of effect on boiler efficiency of side-wall blocks, both bare and refractory covered.	Philadelphia Elec. Co.	Philadelphia Elec. Co.	In progress.	
Effect of variation of CO_2 on superheat.	Waco steam-elec. sta., Texas Power & Light Co., Dallas.	Texas Power & Light Co.		
Investigation of effect of cross-baffle installed in Stirling boilers.	Cleveland Elec. Illum. Co.	Cleveland Elec. Illum. Co.	Completed 1929.	Exit flue-gas temperatures same, capacity increased, water level not so stable as with regular baffles.
Boiler tests using lignite.	U. of North Dakota; R. L. Sutherland.	U. of North Dakota.	In progress.	

COMBUSTION

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Ignition of methane by heated surfaces.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; P. G. Guest.	U. S. Bureau of Mines.	U. S. Bureau of Mines Paper 475; Jour. Tech. Am. Chem. Soc., Vol. 49, 1927;	
Design of laboratory coal-dust explosion gallery.	U. of Kentucky.	U. of Kentucky.	In progress.	
Kinetics and mechanism of gaseous explosions.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; B. Lewis.	U. S. Bureau of Mines and Carnegie Inst. of Tech.	Jour. Am. Chem. Soc., Vol. 52, No. 8, 1930; Jour. Am. Chem. Soc., Vol. 52, No. 10, 1930.	
Study of stoker drive to reduce plunger wear due to angularity of connecting rod.	American Engineering Co.	American Engineering Co.	Completed.	Straight-line drive developed.
Investigation of automatic dampers for controlling air flow through fuel bed.	American Engineering Co.	American Engineering Co.	In progress.	An installation of automatic dampers is now being studied.
Effect of high-temperature preheated air on burning and wasting away of stoker parts.	American Engineering Co.	American Engineering Co.	In progress.	Has resulted in use of Carbofrax for certain stoker parts.
Effect of high-temperature preheated air on softening of coal.	American Engineering Co.	American Engineering Co.	In progress.	Method of determining temperature at which heated air softens coal has been determined.
Effect of high-temperature preheated air on expansion of stoker parts.	American Engineering Co.	American Engineering Co.	Completed.	Data collected make stoker design possible.
Investigation of pulverized-coal furnace that would collect a large part of the coal ash as molten slag.	Babcock & Wilcox Co.	Babcock & Wilcox Co.	In progress.	Furnaces having slag-tap floors and block-covered furnace walls covered with liquid slag collect from two to four times as much ash as is recovered in a dry furnace.
New theory on effective combustion.	Dresden, Germany; P. Rosin.	Committee on fuel of Reichskohlenrat.	Archiv fuer Waermewirtschaft und Dampfkesselwesen, No. 4, 1930, and Feuernugstechnische Bul. 2; completed 1929.	
Study on the application of secondary air.	Dresden, Germany; P. Rosin, R. Fehling.		Archiv fuer Waermewirtschaft und Dampfkesselwesen, No. 4, 1930, and Feuerungstechnische Bul. 2; completed 1929.	
Characteristics of fuel beds on grates.	Dresden, Germany; P. Rosin.	Committee on fuel of the Reichskohlenrat and V.D.I.	Completed 1931.	
Studies on aerodynamic conditions governing flow of air through fuel beds and grates as it relates to emission of fly coke.	Hannover, Germany; E. Arend.	V.D.I. and Dampfkessel-Uberwachungs Verein, Hannover.	In progress.	
Laboratory studies on quantity of combustion air as determined by weight of fuel burned per square foot of grate per hour, depth of fuel bed and class of fuel, and on the variation of velocity of combustion.	Essen, Germany; F. Schulte.	Committee on fuel of the Reichskohlenrat and Verein zur Ueberwachung der Kraftwirtschaft der Ruhrzechen.	In progress.	
Responsiveness to changes in load of various grates and furnaces.	Dresden, Germany; P. Rosin, E. Rammler, J. W. Kauffmann.	Committee on fuel of the Reichskohlenrat and Elecktrowerke, Berlin.	Braunkohle, No. 12-13, 1930 Feuerungstechnische Bul. 4; completed 1930.	
Experiments with large traveling grates.	Essen, Germany; H. Presser.	V.D.I. and Verein zur Ueberwachung der Kraftwirtschaft der Ruhrzechen.	Glueckauf. No. 29, 1929; Feuerungstechnische Bul. 4; completed 1929.	
Ignition and combustion of pulverized coal under high pressure.	Munich, Germany; Prof. Nusselt, W. Wentzel.	Committee on fuel of the Reichskolenrat.	Berichtfolgen des Kohlenstaubausschusses des Reichskohlenrates, No. 18; completed 1930.	
Distribution of temperature, heat exchange and progress of combustion in a pulverized- fuel boiler furnace.	Düsseldorf, Germany; E. Kuhn.	Committee on fuel of the Reichskolenrat and Verein Deutscher Eisenhüttenleute.	Berichtfolgen des Kohlenstaubausschusses des Reichskohlenrates, No. 21; completed 1929.	
Research on Aero-separators.	Dresden, Germany; P. Rosin, E. Rammler.	Committee on fuel of the Reichskohlenrat.	Zement. No. 26/32, 1929; completed 1929.	
Responsiveness of a pulverized-lignite furnace to changes in load.	Dresden, Germany; P. Rosin, E. Rammler, H. Zevner.	Committee on fuel of the Reichskohlenrat and State of Saxony's Elec. Power Supply Co.	Waerme, April, 1931; completed 1930.	
Experiments on burning pulverized coal in narrow furnaces.	Dresden, Germany; P. Rosin, R. Fehling.	Committee on fuel of the Reichskohlenrat.	Pub.-Brounkohle, No. 36, 1930, and Feuerungstechnische Bul. 5, completed 1930.	
Study of change in physical properties of fuel during ignition.	Dresden, Germany; P. Rosin.	Committee on fuel of the Reichskohlenrat.	In progress.	

CONDENSERS

Chlorination of condenser circulating water	Commonwealth Edison Co.	Commonwealth Edison Co.	Completed 1930.	Results show treatment affects algae growth and is both practical and profitable.
Investigation of cleaning effect of chlorinated circulating water.	Pub. Serv. Elec. & Gas Co., Newark, N. J.; V. M. Frost.	Pub. Serv. Elec. & Gas Co.	Reported in paper before met. sec. of A.S.M.E., Nov., 1929; in progress.	Chlorine treatment keeps condenser clean for longer period than other methods. Heat transfer increased 75 to 100 B.t.u.
Studies of chlorinating condenser circulating water.	Philadelphia Elec. Co.	Philadelphia Elec. Co.	In progress.	
Investigation of chlorinating condenser cirlating water.	Detroit Edison Co.	Detroit Edison Co.	In progress.	
Test to determine resistance to condenser tube movement when packed with fiber subjected to water soaking.	Brooklyn Edison Co.	N. Y. Edison system.	Prime Movers Report on Condensing Equipment, July, 1930; completed 1930.	About 600 lb. required to move tube 0.1 in. Similar test on soft metallic packing required less force.
Test on condenser hotwell pumps.	Ingersoll Rand Co.	Ingersoll-Rand Co.	Completed 1930.	A condenser hotwell was installed with glass manholes through which internal operation could be observed and pump tested under all conditions of load, vacuum and water level.
Investigation of action and forces applied by condenser tubes as they expand at various operating temperatures.	Ingersoll Rand Co.	Ingersoll-Rand Co.	Completed 1931.	Tests were run on tubes using various standard types of packing and with tubes expanded in tube sheet.

CONDENSERS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation of the absorption of carbon dioxide from flue gas by the circulating of water in a spray pond for the purpose of preventing formation of carbonate scale in condenser and piping.	Oklahoma Gas & Elec. Co.	Oklahoma Gas & Elec. Co.		
Investigation of steam-jet vacuum pump performance with high-pressure steam.	Ingersoll Rand Co.	Ingersoll Rand Co.	In progress.	Steam compressor installed for this test work.
Comparison of heat transfer through ambrac and admiralty metal condenser tubes.	Ingersoll Rand Co.	Brooklyn Edison Co.	Prime Movers Report on Condensing Equipment, 1930; completed 1929.	
Investigation of heat transmission in surface condensers for steam engines.	Eng. lab. Technical U., Charlottenburg, Berlin; G. Jungnitz.		Completed 1931.	
Heat conductivity in condenser.	Sumitomo Copper Drawing & Steel Tube Co., Japan; D. Yamada.	Sumitomo Copper Drawing & Steel Tube Co.	Completed.	
Protection of condenser tube against corrosion.	Sumitomo Copper Drawing & Steel Tube Co., Japan; K. Inamura.	Sumitomo Copper Drawing & Steel Tube Co.	In progress.	
Anti-corrosive properties of tin-plated condenser tube.	Sumitomo Copper Drawing & Steel Tube Co., Japan; T. Tanabe, G. Koiso.	Sumitomo Copper Drawing & Steel Tube Co.	Completed.	
Age cracks of condenser tube.	Hiro Arsenal, I. J. N., Japan; Y. Fujii.	Imperial Japanese Navy.	Completed.	
Influence of cooling-water velocity on the corrosion of condenser tube.	Hiro Arsenal, I.J.N., Japan; Y. Fujii, A. Nakasuji.	Imperial Japanese Navy.	In progress.	
Study on corrosion of condenser tubes due to air liberated from circulating water.	Pub. Service Elec. & Gas Co., Newark, N. J.	Pub. Service Elec. & Gas Co.	In progress.	
Development of method for determining quantities of air and degree of turbulence within condenser water boxes and tubes and correlating results with tube deterioration	Hudson Ave. and Gold St. stations of Brooklyn Edison Co.	Co-op. with A.S.M.E.	A.S.M.E. Trans., Sept.-Dec., 1930	Total air entering condenser found to be from 200 to 340 cu. ft. per min. at about 20 in. Hg vac.
Investigation of failure of upper tubes in second pass of large condenser.		Co-op. with A.S.M.E.	A.S.M.E. Trans.	
Tests to determine effect of air on condenser tube material.		Co-op. with A.S.M.E.	A.S.M.E. Trans.	
Condenser tube corrosion.	Duquesne Light Co., Pittsburgh	Duquesne Light Co.		
General research on condenser tubes.	United Gas Improvement Co.	United Gas Improvement Co.	In progress.	
Condenser tube deterioration.	N. Y. Edison system.	N. Y. Edison system.	In progress	
Experiments to increase life of condenser tubes at Hell Gate station.	N. Y. Edison system.	N. Y. Edison system	In progress.	
Behavior of condenser tubes under simulated service conditions.	Naval Exp. Sta. Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.		

CORROSION

Influence of oxygen on iron and steel.	U. of Harvard; Albert Sauveur.	U. of Harvard	In progress.	
Reduction of pitting by feet-water heating.	C., M., St. P. & P. R.R.; B. C. Kagl.	C., M., St. P. & P. R.R.	Result of 4-yr. test on locomotive reported.	
Investigation of effects of various amounts of oxygen in water on corrosion fatigue limit of boiler steel.	Naval Exp. Sta., Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.		
Corrosion tests of stainless steels.		A.S.T.M.	In progress.	
Pipe corrosion.	Oklahoma Agri. and Mech. College; R. L. Rhoads, George H. Thomas	Oklahoma Agr. and Mech. College.	In progress.	
Corrosion of wrought iron and steel pipe under service conditions.	Johns Hopkins U.; J. C. Smallwood.	National Tube Co.	In progress; reports confidential.	
Investigation of corrosion in district steam-heating mains.	Hall Laboratories, Pittsburgh	Co-op.	In progress.	
Research on corrosion-resistant material for valve bodies and trim.	Henry Souther Eng. Co.	Client.	In progress.	
Corrosion of welded joints.	United Gas Improvement Co.	United Engrs. & Constrs., Inc.	Completed 1929.	Particularly with reference to alkaline solutions on both arc and gas welds.
To determine the resistance of various materials to erosion.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	
Turbine blade erosion.	Duquesne Light Co., Pittsburgh.	Duquesne Light Co.		
Erosion of turbine blading materials by steam.	Naval Exp. Sta., Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.	In progress.	
Suitability of various materials for repairing pitted turbine runners.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Study of metals to resist corrosive action of water for submerged parts of water turbine.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Caustic-embrittlement studies in connection with plant equipment.	Pub. Service Elec. & Gas Co., Newark, N. J.	Pub. Service Elec. & Gas Co.		
Study of mechanism of electrolytic prevention of brass corrosion in steam condensers.	Massachusetts Inst. of Tech.	Stone & Webster Inc.	In progress.	
Studies of electrolytic corrosion.	Pub. Service Elec. & Gas Co., Newark, N. J.	Co-op. with Pennsylvania R.R. and Bell Telephone Co.		
Investigation of effect of stress, time and number of cycles in causing penetration of metal under corrosion.	Naval Engineering Exp. Sta.	Naval Engineering Exp. Sta.	A.S.T.M., June, 1929.	
Corrosion by flue-gas prevention.	U. of Illinois, Dept. of Indus. Chemistry; D. B. Keyes.	Co-op. with Utility Research Comm.	Eng. Exp. Sta. Bulletin 228 and Cir. No. 20; in progress.	
Causes of boiler tube corrosion on gas side.	Armour Inst. of Tech.	Armour Inst. of Tech.	In progress.	
Effect on concrete of acid water from stored bituminous coal.	Consolidated Gas Elec. Light & Power Co. of Baltimore.	Consolidated Gas Elec. Light & Power Co.	Industrial & Eng. Chemistry ' ct. 1929; completed 1929.	Acid water rapidly attacks concrete at first; insoluble film formed that retards rate corrosion proceeds slowly thereafter for indefinite period.
Effect of sulphur water on concrete.	The Detroit Edison Co.	The Detroit Edison Co.	In progress.	

ELECTRICAL

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Variation of the dielectric constant with temperature and frequency.	A. A. Bless.	N.R.C.	Completed 1930.	
X-ray studies of molecular motions in dielectrics under stress.	R. D. Bennett.	N.R.C.	Completed 1930.	Three experiments described.
Influence of surfaces and space charges on apparent conductivity of dielectrics.	F. K. Herzfeld.	A.I.E.E. and N.R.C.	Presented before Amer. Physical Society. Pub. Physical Review, 1929.	
Deterioration of electrical insulating compounds.	N. Y. Edison system.	N. Y. Edison system.	In progress.	Methods have been developed for drying and degasifying oil. Degasified oil stressed electrically and evolved gases analyzed. Two pure hydrocarbons are being synthesized. Methods are being developed for analysis of degradation products. Precision method for determining acidity is being developed.
Vacuum, pressure and temperature conditions, together with breakdown tests on oil and compound-filled electrical joints.	Pub. Serv. Elec. & Gas Co.	Pub. Serv. El. & Gas Co	Completed 1930.	
Investigation of sludging qualities of transformer oils.	Commonwealth Edison Co.	Com'wealth Edison Co.	In progress.	Method has been developed for determining sludging properties of any oil in 50-day test.
Behavior of insulating oils.	Minneapolis Gen. Elec. Co.	Northern States Pr. Co.	Completed 1929.	
Fundamental characteristics of liquid dielectrics.	Bureau of Standards; H. L. Curtiss, G. W. Gardiner.	Utility Research Comm.	In progress.	
Fundamental properties of liquid dielectrics.	Johns Hopkins U.; J. B. Whitehead.	Co-op. of Engineering Foundation.	In progress.	
Conductivity of insulating oils.	Johns Hopkins U.; J. B. Whitehead.	N.R.C.	Completed 1930.	Continuous current characteristics of several insulating oils were studied for time intervals beginning 0.001 sec. after voltage applied.
Electron bombardment of hydrocarbons.	Cornell U.; V. Karapetoff.	A.I.E.E. and N.R.C.	Presented to American Physical Soc. Pub. Physical Review, 1929.	
Effect of cathode ray bombardment on cable compounds and hydrocarbon oils.	Detroit Edison Co.; C. H. Fellows.	Detroit Edison Co.	In progress; three progress reports in 1929.	
Life of impregnated paper as related to the impregnating oil.	Johns Hopkins U.; F. Hamburger, Jr.	Co-op. with N.E.L.A.	In progress.	
Influence of residual air on the life of impregnated paper insulation.	Johns Hopkins U.; J. B. Whitehead.	Co-op. with N.E.L.A.	In progress.	
Fundamental properties of impregnated paper insulation.	Johns Hopkins U.; J. B. Whitehead, W. B. Kouwenhoven.	Co-op. with Utilities Research Comm.	In progress.	
Accelerated life tests of impregnated paper cable insulation.	Harvard U.	N.E.L.A.	Completed 1930.	
Ionization studies in paper-insulated cables.	Harvard U.; C. L. Dawes.	Harvard U.	In progress.	
Thermal conductivity research on impregnated insulated cable.	U. of Wisconsin and M.I.T.	N.E.L.A.	In progress.	
Predetermination of the deterioration of impregnated paper insulation.	Commonwealth Edison Co.; D. W. Roper.	N.R.C.	Presented at annual meeting N.R.C., 1930.	
Study of the mechanism of cable deterioration.	Detroit Edison Co.; C. F. Hirshfeld.	Detroit Edison Co.	Completed 1929, report printed but not published by Association of Edison Illuminating Co.	
Effect on switchboard wire of abrasion humidity, flame, bends and various solutions.	Philadelphia Elec. Co.	Philadelphia Elec. Co.	Completed 1930.	
Ageing tests of control cable.	Pub. Ser. Elec. & Gas. Co.	Pub. Serv. Elec. & Gas Co.	In progress.	
Absorbtion, drip and cracking tests on weather-proof wire.	Philadelphia Elec. Co.	Philadelphia Elec. Co.	Completed 1930.	Tests resulted in improved specifications.
Weather-proof insulation for line wires.	Elec. Eng. Lab. of Purdue U.; Prof. C. F. Harding.	Utilities Research Comm. Chicago, Ill.	In progress.	
Effect of temperature, pressure and frequency on the electrical properties of rubber.	H. L. Curtis.	A.I.E.E. and N.R.C.	Presented before American Physical Soc. Physical Review, 1929.	
Determination of methods for making life test on rubber insulation.	Detroit Edison Co.	Detroit Edison Co.	In progress.	
Lightning.	State College of Washington; H. V. Carpenter, O. E. Osburn.	State College of Wash.	In progress.	
Protection of instrument tranformers against lightning surges.	Elec. Eng. Lab. of Purdue U.; Prof. C. F. Harding.	Utilities Research Comm.		
Lightning protection for transformer secondaries.	Purdue U.; Prof. C. F. Harding, C. S. Sprague.	Utility Research Comm.	Completed 1931.	25 per cent of failures due to lightning entrance through low-voltage side.
Effects of lightning on transformer secondaries.	Purdue U.; Prof. C. F. Harding, C. S. Sprague.	Purdue U.	In progress.	
Effect of lightning arrester at intervals of 1,000 ft.	Detroit Edison Co.	Detroit Edison Co.	Completed 1930.	
Lightning surges on regulators.	Detroit Edison Co.	Detroit Edison Co.	Completed 1930.	Regulators act as a reflection point, producing high voltage on substation pothead.
Lightning surges in cable.	Croton, Mich.	Detroit Edison Co. Co-op. with Consumers Power Co. and G. E. Co.	Completed 1929.	
Lightning studies involving experiments with auto-valve lightning arresters; measurement of tower-to-ground resistance. Studies of transmission-line phenomena during lightning flashover.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Development of cathode ray oscillograph.	Elec. Eng. Lab. of Purdue U.; R. H. George, inventor.	Eng. Exp. Sta. Purdue U.	A.I.E.E. proceedings of 1929.	This oscillograph has a greater frequency range than any other on the market.
Optical oscillograph design for recording lightning strokes.	Calif. Inst. of Tech., Dept. of Elec. Eng.; K. M. Wolfe.	Calif. Inst. of Tech.	In progress.	
Methods of test relating to electrical insulating materials.		A.S.T.M.	Completed 1930; report of Com. D-9 on electrical insulating materials methods of tests developed by A.S.T.M.	

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Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Determination of magnitude and duration of initial transient magnitizing current on large transformer banks.	Commonwealth Edison Co.	Commonwealth Edison Co.	Completed 1930.	Occasionally starting transients were equivalent to double full-load current, decreasing to one-third initial value in 5 sec.
Study to determine safe loading of power transformers on typical daily load cycles	N. Y. Edison system.	N. Y. Edison system.		
Open delta vs. closed-delta transformer connection.	Detroit Edison Co.	Detroit Edison Co.	Completed 1929.	Open-delta transformers, carrying single-and-three-phase load where single-phase is more than 50 per cent of total, gives better transformer efficiency.
Kinematic study of a solenoid-operated oil circuit breaker mechanism.	U. of Michigan; C. W. Good.	Detroit Edison Co.	In progress.	
Oil circuit breaker tests.	Commonwealth Edison Co., at Crawford Ave.	Commonwealth Edison Co. co-op. with other utilities.	Completed 1930.	Tests showed that on any 12-kv. circuit protected by reactors a 3-phase short circuit would pass practically unnoted if interrupted in less than 8 cycles.
Study of corrosion resistance for chromium-steel alloy used in switch mechanisms.	N. Y. Edison system.	N. Y. Edison system.	Completed 1930.	
Experiments with high-voltage vacuum switches.	Calif. Inst. of Tech. Dept. of Elec. Eng.; R. W. Sorensen, Pleasants.	Calif. Inst. of Tech.	In progress.	
Study and application of methods and equipment for baking out large mercury-arc rectifiers.	Commonwealth Edison Co.	Commonwealth Edison Co.	In progress.	High-current low-voltage method employed to drive out gases.
Experiments on mercury-arc rectifiers to determine the variation and magnitude of residual charging currents during short circuit on a single anode.	Baden, Switzerland; Brown Boveri & Co.	Brown Boveri & Co.	Completed 1930.	
Effect of temperature upon the registration of watt-hour meters on polyphase meters and relays.	U. of Illinois, Dept. of Elec. Engrg.; E. B. Paine.	U. of Illinois.	In progress.	
Effect of illumination on meter testing.	U. of Illinois.	Eng. Exp. Sta. and Dept. of Elec. Engrg.	In progress.	To determine what influence illumination has upon accuracy of meter test made by metermen.
Effect of power factor on watt-hour meter accuracy.	U. of Illinois, Dept. of Elec. Eng.; E. B. Paine.	U. of Illinois.	In progress.	
Polyphase reactive volt-ampere measurement.	U. of Illinois.	Eng. Exp. Sta. and Dept. of Elec. Eng.	In progress.	To determine the effect of unbalanced load or voltage upon the correctness of registration of meters using the various standard connections.
Investigation of methods of measuring reactance power in alternating-current circuits.	Yale U., Dept. of Elec. Eng.; Archer E. Knowlton, T. A. Abbott.	Yale U.	In progress.	
General properties, performance and design of universal electric motors.	Ohio State U.; A. F. Puchstein, E. E. Kemberly.	Ohio State U. Eng. Exp. Sta.	Eng. Exp. Sta. Bulletin 53, 1930.	
Investigation of the phenomenon of "copper-picking" and of the mechanism of the passage of current from slip-ring or commutator to brush.	H. G. Taylor.		I.E.E. Jour. Vol. 68 p. 1356, Oct., 1930.	The variation of contact voltage drop with speed, brush pressure and current is shown. At speeds 10,000 f.p.m. an air film is drawn between brush and ring.
Making a study of the alternating-current single-phase shunt motor, investigating it theoretically and experimentally.	Yale U., Dept. of Elec. Eng.; W. J. Holman, Jr.	Yale U.	In progress.	
Single-phase motors research.	U. of Michigan; Prof. Benj. F. Bailey.	Detroit Edison Co.	Completed 1930.	Investigation culminated in some very desirable improvements now incorporated in the design of such motors and regularly manufactured.
Stationary commutator rectifiers.	Calif. Inst. of Tech., Dept. of Elec. Eng.; Stipp and Strong.	Calif. Inst. of Tech.	In progress.	
Study of load losses in large synchronous machines.	U. of Southern Calif.	U. of Southern Calif.	In progress.	
Investigation of characteristics of frequency changers in parallel operation.	N. Y. Edison system.	N. Y. Edison system.		
Oscillograph records of wave forms in armature of synchronous converter.	U. of Southern Calif.	U. of Southern Calif.	In progress.	
Effect of triple-frequency harmonics in generators of voltage waves in unbalanced power systems.	U. of Southern Calif.	U. of Southern Calif.	In progress.	
Study of alternator field forms.	U. of Arkansas; W. B. Stetzner.	U. of Arkansas.	In progress.	
Determination of skin effect for large copper buses at commercial frequencies.	N. Y. Edison system.	N. Y. Edison system.	Completed 1930.	Measurements made on miniature buses at high frequencies.
Current-carrying capacity of iron pipe.	N. Y. Edison system.	N. Y. Edison system.	Completed.	
Investigation of ground resistance of elec. tower footings.	Philadelphia Elec. Co.	N.E.L.A.	Completed 1930.	
Grounding of electric circuits in high-resistance soils.		Inter company and Utility Research Comm.	In progress.	
Value of stray currents to underground metallic structures.	New Orleans Pub. Serv., Inc.	New Orleans Pub. Serv., Inc.	In progress.	Results to date indicate piping is protected from natural soil corrosion by stray currents.
Non-sinusoidal voltages and currents in polyphase electrical circuits and apparatus.	Pennsylvania State College; L. A. Daggett.	Pennsylvania State College Eng. Exp. Sta.	Pub. Penn. State Eng. Exp. Sta. Bulletin 38, 1930.	
Study of turbine-generator ventilation.	Mitsubishi Elec. Eng. Co., Japan; T. Furumaru.	Mitsubishi Elec. Eng. Co.	In progress.	
Theoretical study of the commutator type frequency changer.	Tokyo College of Eng., Japan; S. Ozawa.	Tokyo College of Eng.	In progress.	
Calculated strength of heavy generator field winding shroud rings.	A. E. G. Turbine Works, Germany; Prof. Schwerin.	A. E. G. Turbine Works.	Completed 1931.	Added centrifugal stresses set up by unbalanced conditions are computed.
Distribution of losses in 200-amp. iron-cell rectifier.	Meiji College of Eng., Japan; S. Saneto.	Meiji College of Eng.	In progress.	
Abnormal voltage arising in mercury rectifier.	Hitachi Eng. Works, Japan; T. Hata.	Hitachi Eng. Works.	In progress.	
Study on the mercury rectifier.	Mitsubishi Elec. Eng. Co., Japan; T. Hamada.	Mitsubishi Elec. Eng. Co.	In progress.	
Researches on the copper sub-oxide rectifier.	Electrotech. Lab. Dept. of communication, Japan; C. Nemoto, S. Kaneko.	Dept. of Communication.	In progress.	

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Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation of electrical properties of various oils.	Elec. Res. Inst. Tokyo Municipality, Japan; H. Numakura.	Elec. Res. Inst. Tokyo Municipality.	In progress.	
Study of corona discharge in insulating oils.	Tech. College of Tokyo Imp. U., Japan; H. Yamashita, T. Kumada.	Tokyo Imp. U.	In progress.	
Study of high-voltage phenomena of insulating oils.	Tech. College of Tokyo Imp. U., Japan; T. Nishi, Y. Arakawa.	Tokyo Imp. U.	Bul. Inst. Phys. Chem. Res Dec., 1929; completed.	
Investigation of dielectric strength of mineral oils and insulating properties of woods.	Tokyo College of Eng., Japan; M. Fukuda.	Tokyo College of Eng.	In progress.	
Determining characteristics of dielectric materials in the high-tension d.c. circuit.	Fujikura Elec. Wire Mfg. Co., Japan; C. Suyemitsu, S. Tsuyuki.	Fujikura Elec. Wire Mfg. Co.	Completed.	
Relations between the porosity and dielectric loss of insulating paper.	Fujikura Elec. Wire Co., Japan; C. Suyemitsu, S. Tsuyuki.	Fujikura Elec. Wire Co.	Completed.	
Investigation of electric properties of paper impregnated with petroleum and resin mixtures.	Elec. Res. Inst. Tokyo Municipality, Japan; H. Numakura.	Elec. Res. Inst. Tokyo Municipality.	Completed.	
High voltage d.c. puncture test of paper-insulated cables.	Yokohama Elec. Wire Co., Japan; S. Hayashi.	Yokohama Elec. Wire Co.	Completed 1930.	
Determining the durability of rubber-insulated wire.	Sumitomo Elec. Wire Mfg. Co., Japan; T. Yamasaki.	Sumitomo Elec. Wire Mfg. Co.	In progress.	
Characteristics of rubber-insulated wire and the relations between ageing and insulation of rubber.	Nippon Elec. Wire Mfg. Co., Japan; S. Numajiro, N. Misuna.	Nippon Elec. Wire Mfg. Co.	Completed.	
Relations between temperature and permeability of sheet iron for integrating wattmeter.	Elec. Res. Inst. Tokyo Municipality, Japan; K. Adachi.	Elec. Res. Inst. Tokyo Municipality.	In progress.	
Researches on the frictional resistance of integrating wattmeter.	Elec. Res. Inst. Tokyo Municipality, Japan; K. Adachi.	Elec. Res. Inst. Tokyo Municipality.	Completed.	
Researches on the wattmeter and integrating wattmeter.	Yonezawa Tech. College, Japan; F. Goto.	Yonezawa Tech. College.	In progress.	
Study induction type integrating wattmeter with special reference to its frictional and temperature coefficient characteristic curve, and its design.	Electrotech. Lab. Dept. Communication, Japan; T. Nakawo, S. Jimbo, K. Suda.	Dept. Communication.	In progress.	
Testing method for electrical carbon brushes.	Res. Office, J. G. R., Japan; R. Kimura.	Japanese Government Railway.	In progress.	
Testing three-phase induction motor with aluminum winding.	Tech. College Tokyo Imp. U., Japan; S. Seto.	Tokyo Imp. U.	In progress.	
Development of a propeller-type fan to cool large turbine-generators internally.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; C. J. Fechheimer.	Westinghouse Elec. & Mfg. Co.		It was found that with the propeller-type fan, as compared with the centrifugal type, machines of double the capacity could be cooled internally, and with fan efficiency as high as 57 per cent.
Effect of hydrogen on commutation and current collection.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.; T. Spooner, R. M. Baker.	Westinghouse Elec. & Mfg. Co.	Mid-winter convention, A.I.E.E., 1931.	Electrical loss at the contact is in general much less in hydrogen than in air, although wear of the brushes in hydrogen, if sparking occurs, may be very great. Operation of carbon brushes and brass collection rings in hydrogen was found to be quite satisfactory.
Application of hydrogen cooling to turbine-generator field.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; C. J. Fechheimer.	Westinghouse Elec. & Mfg. Co.	Electric Jour., March, 1930, p. 165; Electrical Engineering, March, 1931.	The turbine-generator cannot be totally inclosed, making it necessary to have a hydrogen-tight seal on the rotating shaft. A machine embodying this principle was constructed, tests made, and an automatic hydrogen alarm designed.
Fatigue tests of model turbine-generator rotors.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; R. E. Peterson.	Westinghouse Elec. & Mfg. Co.	Mech. Eng., March, 1930.	This equipment for testing model rotors makes it possible to study the possibilities of various designs to the end that the safety of large units be further assured.
Study of helical groove slip-ring and commutator.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; T. Spooner, G. M. Little.	Westinghouse Elec. & Mfg. Co.	Mid-winter convention, A.I.E.E., 1931.	Helical groove eliminates unequal current distribution in a single brush or between several parallel-operated brushes. It also causes a slight increase in contact resistance, which aids commutation.
Extensive study of arc interrupting phenomena, using the information obtained to design a circuit breaker.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; H. M. Wilcox.	Westinghouse Elec. & Mfg. Co.	A.I.E.E., Oct., 1928, Vol 47, p. 1398; A.I.E.E., April, 1929, Vol. 48, p. 528; Electric Jour., March, 1929.	The result of the information gathered on arc interruption is the commercial air circuit breaker. It is now built in sizes up to 25 kv.
Investigation of electric arc rupture under oil.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; J. Slepian, C. L. Denault, H. M. Wilcox, B. P. Baker.	Westinghouse Elec. & Mfg. Co.	Trans. A.I.E.E., p. 421 Vol. 49; Quarterly Trans. A.I.E.E., April 1930, p. 431; Electrical World, April 19, 1930.	Deion-Grid breaker was developed which used the gas formed by the action of the arc on the oil more efficiently in effecting extinction of of the arc.
Investigation of deionizing effect of gas and its application to lightning arresters.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; J. J. Torok.	Westinghouse Elec. & Mfg. Co.	Mid-winter convention, A.I.E.E., Jan., 1931.	Experimental Deion arrester developed consists of a small fiber tube with electrodes at each end. When overvoltage occurs, an arc forms between electrodes, but is quickly extinguished by gases formed from decomposition of the fiber tube.
Lightning investigations.	General Electric Co. Labs. at Schenectady, Pittsfield and in the field.	General Electric Co.	In progress.	An extensive investigation in progress some years in both laboratory and in the field in conjunction with several power companies.
Lightning studies of transformers.	General Electric Co.; F. F. Brand, K. K. Palueff.	General Electric Co.	A.I.E.E., 1929, pp. 998-1012.	Cathode-ray oscillograph studies to co-ordinate strength of transformers and transmission-line insulation under lightning conditions.
Factors affecting the performance and application of lightning arresters.	General Electric Co.; H. M. Towne.	General Electric Co.	G. E. Review, 1929, pp. 428-436.	The action of arresters under different conditions of service.
Field tests on thyrite lightning arresters.	General Electric Co.; K. B. McEachron, E. J. Wade.	General Electric Co.	G. E. Review, 1931, pp. 247-257.	

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Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Mercury-arc rectifier research.	General Electric Co.; A. W. Hull, H. D. Brown.	General Electric Co.	To be published.	
Loading transformers by temperature.	General Electric Co.; V. M. Montsinger.	General Electric Co.	A.I.E.E., 1930, p. 293.	
Dielectric coefficient and dielectric loss in a viscous mineral insulating oil.	General Electric Co.; H. H. Race.	General Electric Co.	To be published.	Variation of coefficient with temperature and frequency studied.
Investigations of oil-filled cables.	General Electric Co.; G. B. Shanklin, F. H. Buller.	General Electric Co.		
Some electric characteristics of cable oils.	General Electric Co.; H. H. Race.	General Electric Co.	To be published.	
Joints in heavy electric conductors.	General Electric Co.; E. G. Bern, W. Specht.	General Electric Co.	G. E. Review, 1930, pp. 389-393.	
Heating and current-carrying capacity of bare conductors.	General Electric Co.; O. R. Schurig, C. W. Frick.	General Electric Co.	G. E. Review, 1930, pp. 141-157.	Including effects of conditions of exposure.
Volt-ampere measurement.	General Electric Co.; John Auchincloss.	General Electric Co.	G. E. Review, 1929, pp. 103-105.	Power-factor considerations; influence of leading and lagging power factor and phase sequence.
Protection of power-transmitting circuits.	General Electric Co.; E. M. Hunter.	General Electric Co.	G. E. Review, 1930, pp. 100-103.	Effect of corona on ground wire.
High-speed photographs of arcs in liquids.	General Electric Co.	General Electric Co.	Elec. World Feb. 14, 1931.	Analysis of behavior of arcs under such conditions.
Effect of armature circuit resistance on stability of synchronous machines.	General Electric Co.; C. A. Nickle, C. A. Pierce.	General Electric Co.	Trans. A.I.E.E., Jan., 1930, p. 338.	

FEED WATER

Effect of pressure and temperature on the behavior of salts in boiler feed water.	U. of Illinois.	U. of Illinois and Utility Research Comm.	In progress.	
Investigation of scale prevention and limitation of boiler water alkalinity.	Ore boats between Erie and Duluth.	Bull & Roberts for Hall Laboratories Inc.	Completed 1930.	
Development of methods for determining hydroxide, carbonate, phosphate and sulphate content of boiler water and testing adaptability to field practice.	Hall Laboratories, Pittsburgh; R. E. Hall.	Hall Laboratories, Inc.	In progress.	Differences in results caused by methods by which reactions are allowed to proceed.
Study of priming and foaming in boiler feed water.	Ohio State U.; C. W. Foulk.	Sponsored jointly by: A.W.W.A., N.E.L.A., A.S.M.E., A.S.T.M., A.R.E.A., A.B.M.A.	In progress.	
Foaming and priming of boiler water.	Ohio State U.; C. W. Foulk.	Ohio State Eng. Exp. Sta. and Dept. of Chem.	"A Theory of liquid film formation" Industrial and Engineering Chemistry, Vol. 21, p. 815, 1929; completed 1929.	All kinds of finely divided solid matter do not promote foaming of dilute salt solutions. Some kinds of solids that do promote foaming lose this power after several hours of boiling.
Feed-water treatment: (1) can steel be developed that is resistant to caustic embrittlement; (2) development of new enhibiting agent; (3) can enhibiting action of sulphate be fully explained.	U. of Illinois; F. G. Straub.	Utilities Research Comm.	Completed 1930.	
Feed-water and boiler-water tests.	State College of Washington; H. F. Lickey.	State College of Washington.	In progress.	
Study of factors involved in development of caustic embrittlement of boiler steel.	Minneapolis Gen. Elec. Co.	Northern States Power Co., Byllesby Eng. & Management Co.		
Control of boiler-water treatment to prevent embrittlement.	U. of Illinois; F. G. Straub.	Utility Research Comm.—Joint Feed Water Committee co-op.	Mech. Eng., May, 1929.	
Embrittlement in boilers.	U. of Illinois and in plants; F. G. Straub.	Utilities Research Comm.	Bulletin 216, U. of Illinois Eng. Exp. Sta.; completed 1930.	
Studies of caustic embrittlement failures.	U. of Michigan; Prof. A. E. White, R. Scheidewind.	Various.	In progress.	The failures due to caustic embrittlement have been identified and their characteristics studied.
Research on boiler-water problems has been carried on continuously under the Detroit Edison Fellowship in Chemical Engineering since July, 1925.	U. of Michigan; Prof. A. H. White, E. P. Partridge.	Detroit Edison Co.	Studies on the mechanism and rate of formation and the thermal conductivity of boiler scale, together with a summary of all previous investigations relating to scale were published in June, 1930, in Bulletin 15 of the Department of Engineering Research; in progress.	Solubility studies on calcium carbonate and calcium sulphate in complex solutions at boiler temperatures now nearing completion point to a considerable revision in the value of the sulphate-carbonate ratio necessary for the prevention of anhydrite scale. This work has also shown that the customary methods for the determination of carbonate in boiler waters are inaccurate, and has resulted in the development of a new method.
Formation and properties of boiler scale.	U. of Michigan; E. P. Partridge.	U. of Michigan.	Bulletin 15, Dept. Eng. Research, U. of Michigan, 1930.	
Mechanism of formation of calcium sulphate boiler scale.	U. of Michigan; E. P. Partridge, A. H. White.	U. of Michigan.	Ind. Eng. Chem. Vol. 21, pp. 834-838, 1929.	
Solubility of calcium sulphate from 0 to 200 degrees.	U. of Michigan; A. H. White.	U. of Michigan.	J. Am. Chem. Soc. Vol. 51, pp. 360-370, 1929.	
Crystal forms of calcium sulphate.	U. of Michigan; E. P. Partridge, L. S. Ramsdell.	U. of Michigan.	Am. Mineral, Vol. 14, 59-74, 1929.	
Formation and thermal effects of calcium sulphate boiler scale.	U. of Michigan; E. P. Partridge, A. H. White.	U. of Michigan.	Trans. A.S.M.E. Vol. 51, pp. 383-394, 1929.	
Thermal effects of boiler scale.	U. of Michigan; E. P. Partridge, A. H. White.	U. of Michigan.	Ind. Eng. Chem. Vol. 21, pp. 839-844, 1929.	
Boiler-water treatment: the method consists in evaporating the water and introducing it into the system as "make-up" steam instead of "make-up" water.	Oregon State Agr. College, Dept. of Mech. Eng.; Prof. F. G. Baender.	Oregon State Agr. Col.	In progress.	It is very likely that a simple effective and inexpensive method will be developed that will take all impurities from the water and collect these impurities without any scale formation within the evaporator.
Investigation of boiler No. 28 Delray power plant for evidence of caustic embrittlement.	Delray Plant.	Detroit Edison Co.	In progress.	

FEED WATER

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Study of phosphates to develop more effective types.	Hall Laboratories.	Hall Laboratories, Inc.	Completed 1929.	
Acid feed control by pH value.	Commonwealth Edison Co.	Commonwealth Edison Co., co-op. with manufacturer.	Completed 1930.	Effort to develop automatic control led to impractical refinements.
Investigation of chemical fixation of oxygen.	Hall Laboratories. Pittsburgh; R. E. Hall.	Hall Laboratories, Inc.	In progress.	
Effect of surge tank sealing on oxygen content of water.	N. Y. Edison system.	N. Y. Edison system.	Completed 1930.	
Studies of moisture in steam at high rates of evaporation.	N. Y. Steam Corp., Kips Bay.	N. Y. Steam Corp.	Presented Metropolitan sec. A.S.M.E. April 1, 1929; completed 1929.	
Investigation of causes for conflicting statements as to the remaining hardness in effluent water from a lime-soda softener.	Hall Laboratories, Pittsburgh; R. E. Hall.	Hall Laboratories, Inc.	In progress.	
To determine the causes of the formation of opaque ice, especially at low brine temperatures, and possible remedy for this condition.	U. of Illinois.	Illinois Eng. Exp. Sta., co-op. with Utilities Research Comm.	Progress reported in bulletin No. 219 of the Eng. Exp. Sta.; in progress.	

FLUID FLOW

Measuring fluid velocities by means of the location of nodal points in wave systems.	U. of Minnesota; H. E. Hartig, H. B. Wilcox.	Engineering Foundation.	In progress.	
Calibration of flow nozzles and pipe orifice meters.	U. of Pennsylvania, Civil Eng. Dept.; W. S. Pardoe.	Bailey Meter Co. and General Elec. Co.	Work going on intermittently.	The probable error of an individual observation is less than in the case of the Venturi meter, but the loss of head is much greater.
Discharge through orifices on end of pipe line.	U. of Wisconsin; L. H. Kessler.	U. of Wisconsin.	In progress.	
Characteristics of orifice and nozzle flow in the region of critical Reynolds numbers. Study of oil-metering problems.	Mech. Eng. Lab., Case School of Applied Science; G. L. Tuve.	Case School of Applied Science co-op. with Bailey Meter Co.	In progress.	
Flow of fluids through orifices and weirs.	Eng. Exp. Sta., Purdue U.	Purdue U.	In progress.	
Measurement of flow of fuel oil.	Brown Instrument Co., Philadelphia, Pa.	Brown Instrument Co.	In progress.	Viscosity determination of oil part of program.
Investigation of the effect of change in velocity distribution between the entrance and throat of a Venturi meter upon the meter coefficient.	Lafayette College; E. M. Fernald.	Lafayette College.	In progress.	
Calibrations of Venturi meters.	Civil Eng. Dept., U. of Pennsylvania; W. S. Pardoe.	Builders Iron Foundry and Simplex Valve & Meter Co.	Many tests completed and results published in the Fluid Meters Com. Report of A.S.M.E.; also in Engineering News Record; in progress.	The coefficients vary with the velocity and diameter, but show no relation to Reynolds number.
A centrifugal integrator for Venturi meters.	Civil Eng. Dept., U. of Pennsylvania; E. F. Stover.	U. of Pennsylvania.	In progress.	This is the secondary device of a complete meter for liquids.
Calibration of 21x14 and 12-in. egg-shaped flume meters.	Civil Eng. Dept., U. of Pennsylvania; W. S. Pardoe.	Simplex Valve & Meter Co.	Completed 1929.	These meters are laid on less than critical grade and are used for measuring sewage at outfalls.
Tests of divergent mouth pieces.	Civil Eng. Dept., U. of Pennsylvania; W. S. Pardoe.	U. of Pennsylvania.	In progress.	The 6-degree cone is most efficient in restoration of velocity head. Bell mouths of the exponential type are being made and tested.
Flow measurement of gas at pressures not exceeding 5,000 lb. per sq. in.	Brown Instrument Co., Philadelphia, Pa.	Brown Instrument Co.	In progress.	Included design of suitable manometer for high pressures.
Flow of air through orifices. To determine coefficients for several types of orifices and short tubes.	U. of Illinois.	Mech. Eng. Dept. and Eng. Exp. Sta.	Bulletin 207, U. of Illinois Eng. Exp. Sta.; in progress.	
Influence of inclination on the discharge of air from branch pipes.	Lafayette College; E. M. Fernald.	Lafayette College.	In progress.	
Calibration of weirs.	Purdue U. Eng. Exp. Sta.	Purdue U.	In progress.	
Investigation of steam nozzles.	England.	Inst. of Mech. Engrs.	Completed 1930.	
Flow through pipe orifices at low Reynolds numbers.	F. C. Johansen.		Royal Society Proc. A, Vol. 126, Jan., 1930.	
Study of flow of fluid in pipes—determination of coefficient of discharge for thin plate orifices, flow nozzles and Venturi tubes.	Ohio State U. Mech. Lab.; S. R. Beitler, Paul Baucher.	Bailey Meter Co. co-op.	Progress report A.S.M.E. paper "The Flow of Fluids Through Orifice in Six Inch Pipes"; in progress.	
Loss of energy in flowing liquids in gradually expanding tubes.	U. of Minnesota; J. O. Jones.	U. of Minnesota.	In progress.	
Study of fluid flow in pipes.	Ohio State U; F. W. Marquis, H. Judd, P. Bucher, S. R. Beitler.	Ohio State U.	In progress.	
Loss of head due to sudden and gradual changes of pipe section.	U. of Wisconsin.	U. of Wisconsin.	In progress.	
Study of wrought iron pipe friction.	U. of Wisconsin; L. H. Kessler.	U. of Wisconsin.	In progress.	
Pressure drop in steam fittings and piping.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Friction loss across welded bends and welding elbows.	The Rice Inst.; J. H. Pound.	Rice Inst.	In progress.	
Economics of steam transmission.	State College of Washington; A. C. Abell.	State Col. of Washington.	In progress.	
Efficiency and economy of underground steam distribution systems.	U. of Tennessee Eng. Exp. Sta.; W. R. Woolrich, Leo Holdredge.	U. of Tennessee.	Bulletin 10 of U. of Tenn. Eng. Exp. Sta.	
Economical distribution of steam in district heating.	State College of Washington; A. C. Abell.	State Col. of Washington.	Bulletin 32, Feb., 1930, of State Col. of Washington.	
Study of characteristics of air-flow-steam-flow meter.	Hudson Ave. Plant; W. G. Lauffer.	N. Y. Edison system.	Presented before Metropolitan A.S.M.E., May, 1929.	
Accurate measurements with the aid of a screen to determine discharge coefficients of weirs.	Darmstadt U.; Wagenbach.	Darmstadt U.	Completed 1930.	
Action of nozzles and orifices when measuring viscous fluids.	Danzig U.; Schmidt.	Danzig U.	In progress.	

FLUID FLOW

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Tests made with nozzles and orifices.	Goettingen U.; Prandtl.	Goettingen U.	In progress.	
Influence of nozzle contour on the outflow coefficient in measuring steam flow.	Munich U.; Loschge.	Munich U.	In progress.	
Research on steam flow through V.D.I. standard nozzles and orifices (standard of 1930) at small Reynolds figures.	Eng. Lab. of Tech. U., Charlottenburg (Berlin); Prof. Josse.	Tech. U. of Charlottenburg.	In progress.	
Investigation of efficiency of nozzles (impact method).	Fraser & Chalmers Eng. Wks., Erith, Kent, England.	Fraser & Chalmers Eng. Wks.	In progress.	
Steam flow through centrifugal blowers and compressors.	U. of Danzig; Fluegel.	U. of Danzig.	In progress.	
Investigation of optical methods of the flow in a centrifugal pump.	Hydraulisches Inst. der Technischen Hochschule, Munich, Germany; Dr. Ing. D. Thoma.	Notgemeinschaft der deutschen Wissenschaft.	Mitteilungen des Hydraulischen Inst. der Technischen Hochschule München, Vol. 4, 1931.	
Accuracy of propeller flow meters directed at an angle to the stream flow.	Hydraulic Inst., Munich Tech. U., Germany; Fritz Anlaufft.	Munich Tech. U.	In progress.	Changing position and profile of external shroud ring increased accuracy.
What happens in a centrifugal pump when the power is cut off.	Hydraulic Inst., Munich Tech. U., Germany; D. Thoma.	Munich Tech. U.	In progress.	Hydraulic characteristics observed with pump operating under normal and abnormal conditions, including reversal and operation as turbine.
New apparatus for measuring flow velocity in turbulent water.	Hydraulic Inst., Munich Tech. U., Germany; Gogulapati Gangadharan.	Munich Tech. U.	Completed 1930.	Application of Wheatstone Bridge to measure change in electrical resistance of glass insulated platinum wire immersed in the turbulent water. Proportional changes in electrical current flow due to cooling effect of turbulent water flow are recorded by oscillograph.
Loss of energy in welded angular pipe bends with smooth and rough inside surfaces.	Hydraulic Inst., Munich Tech. U., Germany; Werner Schubart.	Munich Tech. U.	Completed.	The energy loss ratio between rough and smooth surfaces is approximately 2:1. Tests determined required length of intervening straight runs between two 45 deg., three 30 deg., and four 22 deg. angular bends.
Friction losses in conically shaped overlapped pipe and in straight pipe with straight overlapped couplings.	Hydraulic Inst., Munich Tech. U., Germany; O. Poebing, J. Spangler.	Munich Tech. U.	Completed.	Observation showed that the coupled straight pipe offered less resistance to flow than conical type.
Flow losses occurring in "Y" pipe branches.	Hydraulic Inst., Munich Tech. U., Germany; Franz Petermann.	Munich Tech. U.	Completed.	Observations made both with inflow and outflow through "Y" branches and with and without converging branches. "Y" branch of less than 45 deg. reduces loss observed in 90 deg. tee by 60 per cent under similar conditions. Converging branch with rounded connection to main passage is the most efficient both for inflow and outflow.
Hydraulic losses in pipe branch connections.	Hydraulic Inst., Munich Tech. U., Germany; Emil Kinne.	Munich Tech. U.	Completed 1930.	A 45 deg. "Y" joined to 45 deg. knee is 65 per cent more efficient than 90 deg. tee connection.
Form and characteristics of nozzles (mainly steam).	Osaka College of Eng., Japan; M. Hisatake.	Osaka College of Eng.	In progress.	
Flow of water in the upper water chest of low-head water turbine	College of Science & Eng., Waseda U., Japan; S. Ihara.	Waseda U.	In progress.	
Effect of tube edge and tailwater base upon the efficiency of waterwheel.	Tokyo College of Eng., Japan; Y. Matsumoto.	Tokyo College of Eng.	In progress.	
Relations between temperature and frictional loss in viscous fluid.	Osaka College of Eng., Japan; T. Uyematsu.	Osaka College of Eng.	In progress.	
Efficiency of butterfly valve.	College of Science & Eng., Waseda U., Japan; S. Ihara.	Waseda U.	In progress.	
Water flow around the butterfly valve.	College of Science & Eng., Waseda U., Japan; S. Ihara.	Waseda U.	In progress.	
Determination of discharge coefficient in the rectangular weir.	College of Science & Eng., Waseda U., Japan; S. Ihara.	Waseda U.	In progress.	
Fluctuations in the coefficient of Venturi flow meter.	Tokyo College of Eng., Japan; Y. Matsumoto.	Tokyo College of Eng.	In progress.	

FUELS

Heating of Iowa coal in storage.	Des Moines, Iowa; H. L. Olin.	Iowa Geological Survey.		
Distribution of sulphur forms in the Pittsburgh coal bed.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; W. A. Selvig.	U. S. Bureau of Mines, Pittsburgh Coal Company, and Carnegie Inst. of Technology.	Bul. 43, U. S. Bureau of Mines and Carnegie Inst. of Tech., 1929; completed 1929.	
Accelerated slacking test for coal.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; A. C. Fieldner, W. A. Selvig.	U. S. Bureau of Mines.	U. S. Bureau of Mines Report of Investigation 3055, 1930; completed 1931.	
Analyses of coals.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; H. M. Cooper.	U. S. Bureau of Mines.	Many Bureau of Mines Bulletins and tech. papers.	
General characteristics of coals.	United Gas Improv. Co.	United Gas Improv. Co.	In progress.	
Analyzing and testing the coals of Ohio.	Ohio State U.; D. J. Demorest.	Ohio State U.	In progress.	
Investigation of Ohio coals. Problems of combustion in boiler plants of state institutions.	Field tests.	Eng. Exp. Sta. of Ohio State U. and Dept. of Finance, Ohio State.	In progress.	
Investigation of Ohio coals.	Ohio State U.; H. M. Faust.	Eng. Exp. Sta. of Ohio State U. and Dept. of ndustrial Relations of State of Ohio.	Publication of two bulletins during 1931 contemplated.	
Friability of Illinois coals.	U. of Illinois Eng. Exp. Sta.; C. M. Smith.	Illinois State Geographical Survey.	Bul. 218, U. of Illinois Eng. Exp. Sta.	Unit coal studies are nearly complete. Sulphur forms occurring in these coals are being studied. Specific gravity and Phenal extractions, as well as ultimate analysis, are contemplated.
Reclassification of Virginia coals.	Eng. Exp. Sta. of Virginia Polytechnic Inst.; F. H. Fisk, J. A. Addlestone.	Co-op. with U. S. Bureau of Mines.	In progress.	

FUELS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation of physical and chemical properties of West Virginia coals.	West Virginia U.; L. C. Shriver	West Virginia U.	In progress.	
Approximate analysis of Colorado coals.	Colorado Agr. Col.; A. A. Logan.	Colorado Agr. College.	In progress.	
Studies on the behavior of coal under accurately known conditions.	Yale U., Dept. of Chem. Eng.; Prof. Curtis, Mr. Lloyd with two graduate and two undergraduate students.	Yale U.	In progress.	The manufacture of an artificial anthracite from bituminous coal, the conversion of coal to oil, the complete gasification of coal and many similar problems require that there be secured much better and more comprehensive information regarding the behavior of coal under various conditions.
Extensive investigations and researches in coal.	U. of Alberta, Edmonton.	U. of Alberta.	In progress.	
Drying of lignite without disintegration.	U. of North Dakota.	U. of North Dakota.	In progress.	
Coking of lignite.	U. of North Dakota; A. W. Gauger.	U. of North Dakota.	In progress.	
Vapor pressure of lignite.	U. of North Dakota; Irvin Lavine.	U. of North Dakota.	In progress.	
Drying of lignite with waste furnace gases.	U. of North Dakota; R. L. Sutherland.	U. of North Dakota.	In progress.	
Drying of lignite with saturated steam.	U. of North Dakota; Irvin Lavine.	U. of North Dakota.	In progress.	
Method for size analysis of solid fuels.	Berlin, Germany; P. Rosin.	Committee on fuel of the Reichskohlenrat.	In progress.	
Investigation of pneumatic pulverizing.	Muldenstein, Germany; E. Rammler, H. Schwartzkopff.	Committee on fuel of the Reichskohlenrat and German Railroad Administration.	In progress.	
Grindability of various classes of fuel.	Essen, Germany; F. Schulte.	Committee on fuel of the Reichskohlenrat and Verein zur Ueberwachung der Kraftwertschaft der Ruhrzechen.	In progress.	
Determination of specific weight of pulverized coal.	Dresden, Germany; E. Rammler.	Committee on fuel of the Reichskohlenrat.	Completed 1931.	
Sampling powdered fuel from furnace during combustion.	Düsseldorf, Germany; K. Rummel.	Committee on fuel of the Reichskohlenrat and Verein Deutscher Eisenhuttenleute.	In progress.	
Research on testing the properties of ash and relation of laboratory tests to actual behavior of ash in furnaces.	Essen, Germany; A. Baunn, F. Schulte.	Committee on fuel of the Reichskohlenrat and Verein zur Ueberwachung der Kraftwertschaft der Ruhrzechen.	In progress.	
Behavior of the ash on lignite stokers.	Herschfelde, Saxony; E. Rammler.	Committee on fuel of the Reichskohlenrat, State of Saxony's Elec. Power Supply Co.	In progress.	
Separation of ash from high-ash coal.	Arthur D. Little, Inc., Cambridge, Mass.	Arthur D. Little, Inc.	In progress.	
Micropyrometer method for fusibility of coal ash.	Pub. Service Elec. & Gas Co., Newark, N. J.	A.S.T.M. Committee D5 and Bureau of Mines.	Completed 1929.	
Fusion point of ash of various coals and their suitability for use on stokers.	U. of Dubuque; W. B. Zuker.	U. of Dubuque.	In progress.	
Ash-fusion tests, using De Graaf apparatus.	Pub. Service Elec. & Gas Co., Newark, N. J.	Co-op. with A.S.T.M.		
Coal-ash fusibility as related to clinker formation.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; P. Nicholls, W. A. Selvig.	U. S. Bureau of Mines.	Co-op. Bull. 29, U. S. Bur. of Mines, and Carnegie Inst. of Tech., 1926, 64 pp.; A. S. M. E., Fuels & Steam Power, vol. 50, No. 8, Jan.-Apr., 1928, pp. 33-44; A.G.A., 1929, pp. 1068-1079.	
Ash-fusing characteristics of different coals.	Minneapolis General Elec. Co.	Northern State Power Co., U. S. Bureau of Mines.		
Sampling of pulverized coal in coal-air streams.	Ohio State Eng. Exp. Sta. and plant of National Cash Register Co.; D. J. Demarest, A. H. Dierker.	Ohio State U. Eng. Exp. Sta.	In progress.	
Development of method for determining grindability of coal.	Yale U.	Yale U.	In progress.	
Burning pulverized Iowa coal.	Iowa State College Eng. Exp. Sta.; E. B. Smith.	Iowa State College.	Bul. 97, May 1930.	Project revealed that Iowa coals can be used economically as power fuel in pulverized form.
Grindability of coal for pulverizer service.	Fuel Engrg. Co. of N. Y.	Fuel Engrg. Co. of N. Y.	*Power*, Dec. 2, 1930; in progress.	
Composition of tar from low-temperature carbonization of Utah Coal—	U. S. Bureau of Mines, R. L. Brown; and Carnegie Inst. of Tech., R. N. Pollock.	Carnegie Inst. of Tech.	Carnegie Inst. of Tech., Bul. 41.	
Carbonization of crushed coal.	U. of Michigan; A. E. White.	Michigan Gas Assn.	In progress.	Experiments have shown that if coal is crushed to a fineness which will all pass a 20-mesh screen it will be carbonized completely in dropping through an empty tube eight feet high heated to a fair red heat. The gas evolved has a heating value of 500 to 700 B.t.u., and the coke retains 10 to 15 per cent volatile matter, depending upon the temperature and the kind of coal used. The particles of coal are puffed and soft.
Hydrogenation of coal.	U. of Washington; W. L. Benschlein.	U. of Washington.	In progress.	
Hydrogenation of Kansas coals.	Kansas State Agr. College Eng. Exp. Sta.; R. A. Seaton.	Kansas State Agr. Col.	In progress.	
Low-temperature carbonization of sub-bituminous coals.	Colorado College; Dr. Charles C. Microw.	Colorado College.	In progress.	

FUELS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Carbonization of Illinois coal at low temperature.	U. of Illinois; F. B. Hobort.	Utility Research Comm.	Completed 1930.	No process developed offered reasonable chance of profitably processing coal for combined gas and electric plant use.
Destructive distillation of Iowa coal and other utilization studies.	Iowa State College of Agr. and Mech. Arts; G. W. Burke.	Iowa State College of Agr. and Mech. Arts.	In progress.	
Vertical-retort tests of the White process of carbonization.	Ohio State U.; D. J. Demarest.	Ohio State U.	In progress.	
Low-temperature carbonization of different coals and a study of the byproducts obtained.	U. of Tennessee; Charles E. Ferris, Leo Holdredge.	U. of Tennessee.	Bul. 9 of U. of Tenn. Eng. Exp. Sta.; in progress.	
Low-temperature carbonization of coal.	Allis-Chalmers Mfg. Co.; J. Furlong.	Allis-Chalmers Mfg. Co.		Have installed plant for West Virginia Super Fuel Co.
Low-temperature carbonization with reference to oil shales and cannel and bituminous coals.	U. of Kentucky; C. S. Crouse.	U. of Kentucky.		
Study of coking characteristics of Eastern and Southern coals on underfeed stokers.	Brooklyn Edison Co.	Brooklyn Edison Co.	In progress	
A study of the plastic state of coal during coking.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; J. D. Davis.	U. S. Bureau of Mines and Carnegie Inst. of Tech.		
Effect of inerts on the coking properties of Pittsburgh coal.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; J. D. Davis.	Pittsburgh Coal Co.	In progress.	
Survey of methods for determining gas and coke-making properties of American coals.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; A. C. Fieldner, J. D. Davis.	A.G.A.	Proc. A.G.A., 1928, pp. 1164-1189; Proc. A.G.A. 1929, pp. 994-1005; Ind. & Eng. Chem. vol. 22, No. 10, pp. 1113-1123; in progress.	
Coking of semi-anthracite coal of Virginia.	Virginia Polytechnic Inst. Eng. Exp. Sta.; F. H. Fish.	Virginia Polytechnic Inst.	In progress.	Due to high ash content of the coals under examination, the research project has been altered to a briquetting problem. Briquettes made by pressure and heat treatment contain only 3 per cent less volatile than the original coal and may be used as a method of marketing the slack.
Composition of oils and tar from low-temperature carbonization of coal.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; E. B. Kester.	U. S. Bureau of Mines, Carnegie Inst. of Tech. and National Coal Association.	Co-op. buls. 31 (1926), 35 (1928) and 41 (1929) U.S. Bureau of Mines and Carnegie Inst. of Tech.; Ind. & Eng. Chem., vol. 20, 1928, pp. 392-396; Ind. & Eng. Chem. vol. 19, 1927, pp. 26-31; Ind. & Eng. Chem. vol. 21, 1929, pp. 254-258; Coal Age, vol. 29, 1926, pp. 905-906; Proc. Am. Gas Assoc., 1925, pp. 887-899; in progress.	
Blue vs. yellow flame oil burners for domestic heating.	Johns Hopkins U.; A. H. Senner, J. C. Smallwood.	U. S. Dept. of Agriculture.	Completed 1930.	Radiant heat transfer from the blue flame is equally good as, if not better than, the yellow flame. Remarkably high efficiency obtained
Methods for determining the friability of coal	U. S. Bureau of Mines Northwest Exp. Sta., Seattle; H. F. Yancey.	U. S. Bureau of Mines and U. of Washington.	In progress.	
Catalytic oxidation of hydrogen sulphide in fuel gas.	U. of Iowa; Dr. H. L. Olin.	U. of Iowa.	In progress.	
Standardization of agglutinating test of coal.	U. S. Bureau of Mines, Pittsburgh Exp. Sta. and Northwest Exp. Sta., Seattle; W. A. Selvig, H. F. Yancey.	U. S. Bureau of Mines.	Am. Inst. Min. & Met. Engrs., Tech. Pub. 216, June, 1929, 46 pp.; U. S. Bureau of Mines Report of Investigation 3211, 1930; in progress.	
Removal of sulphur compounds from gases.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; H. H. Storch.	U. S. Bureau of Mines.	In progress.	
To develop a method of economical removal of sulphur from coal.	U. of Illinois.	Co-op. with Utilities Research Comm.	In progress.	
Cleaning of coal.	U. S. Bureau of Mines, Northwest Exp. Sta., Seattle, and Southern Exp. Sta., Tuscaloosa; H. F. Yancey, B. W. Gandrud.	U. S. Bureau of Mines, U. of Washington and U. of Alabama.	U. S. Bureau of Mines bul. 300, 1929; U. S. Bureau of Mines Tech. Paper 361, 1925; U. S. Bureau of Mines Report of Investigations 2755 (1926), 2950 (1929), 3012 (1930), 3014 (1930); various journal articles; continuous.	
Washing Iowa coals.	Iowa Geographical Survey, Des Moines, Iowa.	Iowa Geographical Survey.		
River coal dredging experiments to improve quality.	Baltimore, Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Developing and use of device for sampling coal deposits in bed of Susquehanna River.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Accelerated laboratory test for determination of slacking characteristics of coal.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; A. C. Fieldner.	U. S. Bureau of Mines.	Bureau Mines Bul. R.I. 3055, Nov., 1930.	
Utilization of waste natural gas.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; H. H. Storch.	U. S. Bureau of Mines.	In progress.	
Inflammability of gases and vapors.	U. S. Bureau of Mines, Pittsburgh Exp. Sta.; G. W. Jones.	U. S. Bureau of Mines.	U. S. Bureau of Mines Bul. 279, 1930; continuous.	
Ignition and combustion of gas and fuel vapor mixtures.	Mech. Lab., Technical U., Dresden; Dr. Ing. W. Linder.	Technical U., Dresden.	To be published in V. D. I. completed 1930.	
Bomb tests for the determination of ignition limits of hydrogen air mixtures.	Mech. Lab. of the Technical U., Dresden; Dr. Ing. W. Dieterlen.	Technical U., Dresden.	Technische Mechanik and Thermodynamik, 1930.	
Fuel analysis with the bomb, monometer and orsat.	Mech. Lab. Technical U., Dresden; Dr. Ing. F. Bosnychnovc.	Technical U., Dresden.	Archiv fur Waermewerstschaft, 1931.	
Study of properties and requirements of diesel fuels.	American Petroleum Inst.	S.A.E. and A.S.M.E.	Projected.	

FUELS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Comparison of grindability of coal as indicated by two types of grindability machines.	Fuller Lehigh Co.; R. M. Hardgrove.	Fuller Lehigh Co.	Presented A.S.M.E., April, 1931.	
Method of separating high- and low-ash anthracite coal using principle of attraction and repulsion of electric charges.	Westinghouse Electric & Mfg. Co., E. Pittsburgh; C. F. Hill, H. M. Bullard.	Westinghouse Electric & Mfg. Co.		As a laboratory experiment, the method developed was quite satisfactory and looks promising for commercial application to anthracite coal. By analysis it was found that the high-ash side contained 58.1 per cent ash, and the low-ash side 13.5 per cent.

HEAT TRANSFER

Determination of coefficients of heat transfer from tube to water.	England; A. Eagle, R. M. Ferguson.	British Elec. Allied Industries Research Assn.	Proceedings Institution of Mechanical Engineers, No. 4, 1930; completed 1930.	
Thermal and electrical conductivities of materials at high temperatures.	Virginia Polytechnic Inst.; F. B. Haynes, F. L. Robeson.	Virginia Polytechnic Inst.	In progress.	
Investigation in the general field of heat transfer.	U. of Michigan; Prof. W. L. Badger, W. L. McCabe.	Whiting Swenson Co., Ann Arbor, Mich., and the Dept. of Chem. Eng., U. of Mich.	In progress.	Investigation on heat transfer from fluids to metal walls have been carried out at various times. Emphasis has been placed on heat transfer from condensing vapors to metal walls; from metal walls to boiling liquids; and from metal walls to non-boiling liquids of high viscosity.
Heat transfer coefficient determination for various fluids.	U. of Texas; B. E. Short.	U. of Texas.	In progress.	
Transfer of heat between fluids and solids.	U. S. Bureau of Standards.	Johns Manville Co.	In progress.	
Heat conductivity of refractories.	Ohio State U.; A. S. Watts.	Ohio State U.	In progress.	
Thermal conductivity of materials, including refractories and metals.	U. S. Bureau of Standards.	U. S. Bureau of Standards.	In progress.	
Effect of air velocity, humidity and moisture absorption on thermal conductivity.	Pennsylvania State College; F. G. Hechler.	Pennsylvania State Col.	In progress.	
Surface transmission of heat—radiation and convection.	Pennsylvania State College; F. G. Hechler.	Pennsylvania State Col.	In progress.	
Determination of heat transmission through boiler tubes.	U. of Illinois; A. C. Willard.	U. of Illinois.	In progress.	
Determination of heat transmission from gases to tubes and in small boiler models by the absorption method.	Munich, Germany; Prof. Knoblauch.		In progress.	The absorption method was initially employed by Thoma.
Heat absorptions in water-cooled furnaces.	International Comb. Eng. Corp.; W. L. De Baufre.	International Comb. Eng. Corp.	A.S.M.E. Trans., 1930.	Effectiveness factor derived for relating heat radiated to furnace outlet temperature.
Heat transfer rates of condenser tubes of special corrosion-resisting alloys and tube preparations.	Ingersoll Rand Co., Phillipsburg.	Ingersoll Rand Co.	In progress.	Corrosion-resisting preparations in some cases lower heat transfer.
Study of heat emission from tubes placed in a wind tunnel.	Yale U.; L. E. Seeley.	Yale U.	In progress.	One year was devoted to a study of a variety of single tubes, many with extended surfaces. This year the study is being carried on with two tubes to see whether the position of one tube relative to the other will increase or decrease the emission of heat from each tube.
Experiments on heat transfer from hot air to water through steel pipes.	Polytechnic Inst. of Brooklyn; P. R. Kolbe.	Polytechnic Institute of Brooklyn.	In progress.	
Heat transfer in ammonia condensers.	U. of Illinois; A. P. Kratz.	U. of Illinois.	Bulletin 209, U. of Illinois Eng. Exp. Sta., progress report Part III; completed 1930.	
Ammonia transfer coefficients in absorption towers.	U. of Wisconsin; O. L. Kowalke, O. A. Hougen, K. M. Watson.	U. of Wisconsin.	In progress.	
Determination of maximum heat transfer in forced-draft coolers.	Vilter Mfg. Co. research lab.	Vilter Mfg. Co.	In progress.	
Conductivity of pipe covering.	Commonwealth Edison Co.	Commonwealth Edison Co.	Completed 1930.	Long time test to determine effect of time on insulation.
Heat loss from steam pipes.	Montana State College; E. Therkelsen and Jones.	Montana State College.	Completed 1929.	
Experiments on heat-transmission coefficients through commercial magnesia pipe coverings.	Polytechnic Inst. of Brooklyn; P. R. Kolbe.	Polytechnic Institute of Brooklyn.	In progress.	
Study of the efficiency of various kinds of heat-insulating materials.	U. of Oklahoma.	U. of Oklahoma.	In progress.	
Use of aluminum foil with inclosed dead air spaces for heat insulation.	Naval Exp. Sta. Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.		
Tests to determine practical temperature limit for cork paint insulation.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Heat-flow meters and thermal conductivity measurements.	Pennsylvania State College; F. G. Hechler, E. R. Queer.	Eng. Exp. Sta. Pennsylvania State College.	Eng. Exp. Sta. Penn. State Bulletin 37; in progress.	
Construction design and use of a "heat probe."	Munich, Germany; Prof. Knoblauch.		In progress.	The "heat probe" designed by Dr. F. Munzinger is used for quickly measuring heat transmitted by radiation in steam boilers, smelting and heating furnaces.
Application of Osborne Reynold's theory of heat transfer to flow through a pipe.	G. I. Taylor.		Roy. Soc. Proceedings pp. 25-30, Sept. 3, 1930.	Measurements of heat transfer between a brass tube and water flowing through it.
Heat transfer from impact.	Stuttgart Technical School; H. Reiher.		In progress.	Tests confirmed phenomena that more heat is absorbed when heated air stream impinges vertically against iron plate than impingement at any other angle.

HEAT TRANSFER

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Heat transfer through cylindrical layers of gas.	Danzig; W. Beckmann.		Completed 1930.	Measurements were made on gas layers varying from 7 to 300 mm. thickness. Max. insulation obtained with layers 10 to 20 mm. thick.
Determination of heat distribution to obtain factor for calculating heat transfer during flow of air and ammonia mixtures through pipes.	Stuttgart Technical School; W. Hoffmann.		In progress.	Runs of short duration approached calculated factors by Nussett formula, longer runs gave factors of less value.
Determination of heat conductivity of fireproof building materials at temperatures 100 to 1,000 deg. C.	Glass Lab., Osram, G.m.b.H., Germany.	Osram, G.m.b.H.		
Heat transmitted by flow of heated air across pipes and tube bundles.	Stuttgart U., Germany; H. Reiher.	Stuttgart U.	In progress.	
Heat transmitted by a horizontal steam pipe surrounded by cold water at rest.	Munich U.; Nusselt.	Munich U.	In progress.	
Total radiation of CO_2 and steam at high temperatures.	Danzig U.; E. Schmidt.	Danzig, U	In progress.	
Experimental determination of heat transmission from pipe lines to fluids of high viscosity.	Danzig U.; E. Schmidt.	Danzig U.	Completed 1930.	
Determination of heat conductivity factor of insulating materials.	Munich U.; Prof. Knoblauch.	Munich U.	Completed 1930.	
Heat exchange in regenerators.	H. Hausen.	H. Hausen.	Completed 1930.	
Character of the temperature and air velocities in front of a vertical plate, giving up heat by natural convection.	Danzig U.; E. Schmidt, W. Beckmann.	Danzig U.	Completed 1930.	
Heat transfer in jacket-cooled centrifugal compressors.	General Electric Co.; M. G. Robinson.	General Electric Co.	G. E. Review, 1930, pp. 296-301.	
Heat conductivity of the combustion chamber of steam boiler.	Osaka College of Eng., Japan; M. Hisatake.	Osaka College of Eng.	In progress.	
Heat transmitted to oil pipe lines.	Eng. Lab., Danzig Tech. U., Germany; H. Kraussold.	Danzig Tech. U.	Completed 1931.	Effect of flow velocity and viscosity on heat transmitted to oil in pipe lines was investigated.
Heat transfer by mixtures of steam and air.	Eng. Lab., Danzig U., Germany; E. Nessler.	Danzig Tech. U.	In progress.	Numerical constants determined to show effect of air in steam on condenser performance.

HEATING AND VENTILATING

Thermal resistance of air spaces.	U. of Minnesota; F. B. Rowley.	Co-op. with A.S.H.V.E.	A.S.H.V.E. Jour., Jan., 1929.	Data secured on thermal resistance of air spaces 0.128 to 1.5 in. thick at mean temperatures of 20 to 150 deg.
Heat transfer coefficients of building walls measured under natural weather conditions.	A.S.H.V.E. lab. at U. S. Bureau of Mines, Pittsburgh; F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Jour., Feb., 1929; completed.	Over-all thermal conductance data obtained for nine types of building wall construction.
Over-all heat transfer coefficients obtained by test and by calculation.	U. of Minnesota; F. B. Rowley.	Co-op. with A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., May, 1929.	Conductance of built-up wall construction as determined by test and by calculation agree closely.
Heat and air volume output of unit heaters.	U. of Kentucky; L. S. O'Bannon.	Co-op with A.S.H.V.E.	A.S.H.V.E. Jour. Sec. H.P.-A.C., Aug, 1929.	Obtained data on methods of testing unit heaters used by A.S.H.V.E. committee on code for unit heaters.
Air infiltration through various types of brick wall construction.	U. of Wisconsin; G. L. Larson.	Co-op. with A.S.H.V.E.	A.S.H.V.E. Jour., Mar., 1929.	Air leakages as high as 28 cu. ft. per hr. per sq. ft. with 30 m.p.h. wind through 13 in. brick wall.
Capacity of radiator supply branches for one- and two-pipe systems.	Carnegie Institute of Tech., F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., May, 1929.	Capacity of 1 to 2 in. radiator supply branches were determined.
Pipe sizes for hot-water heating systems.	Texas Eng. Exp. Sta.; F. E. Giesecke.	Co-op. with A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., June, 1929, Feb., 1930; in progress.	Capacities of pipes for three hot-water systems were determined.
Heat and moisture loss from human body and its relation to air conditioning.	A.S.H.V.E. lab. at U. S. Bureau of Mines; F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Trans., 1929.	
Effect of air velocity, temperature and surface on surface conductances.	U. of Minnesota; F. B. Rowley.	U. of Minnesota.	A.S.H.V.E. Jour. sec. H.P.-A.C., June, 1930.	
Air infiltration through various types of wood-frame construction.	U. of Wisconsin; G. L. Larson.	U. of Wisconsin.	A.S.H.V.E. Jour. sec. H.P.-A.C., June, 1930.	
Capacity of dry return mains for steam and vapor heating systems.	A.S.H.V.E. lab. at U. S. Bureau of Mines; F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., Aug., 1930.	Capacity of $\frac{3}{4}$ and 1 in. return risers determined for various air quantities.
Capacity of return risers for steam and vapor heating systems.	Carnegie Inst. of Tech.; F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., Oct., 1930.	
Loss of head in submerged orifices.	Texas Eng. Exp. Sta.; F. E. Giesecke.	A. & M. College of Texas.	A.S.H.V.E. Jour. sec. H.P.-A.C., July, 1930.	
Air leakage through various types of building construction.	A.S.H.V.E. lab. at U. S. Bureau of Mines; F. C. Houghten.	A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., Dec., 1930; in progress.	
Wind velocity gradients near surfaces and their effect on film conductance.	A.S.H.V.E. lab. at U. S. Bureau of Mines; F. C. Houghten.	A.S.H.V.E.	Paper at 1931 annual meeting A.S.H.V.E.; completed 1931.	Film conductance is shown to vary from 1.4 to 2.1 for still air to 9.4 to 14 for 30 m.p.h. velocity.
Loss of head due to flow of water through various fittings.	Texas Eng. Exp. Sta.; W. H. Badgett.	A. & M. College of Texas.	In progress.	
Check of Babcock formula as applied to modern piping.		A.S.H.V.E.	Projected.	
Application of copper tubing to steam and hot water heating systems	A.S.H.V.E. lab. at U. S. Bureau of Mines.	A.S.H.V.E. and Assoc. Copper Tubing Mfg.	In progress.	
Determination of conductivity of homogeneous building and insulating material.	U. of Minnesota.	Co-op. with A.S.H.V.E.	In progress.	Heat flow through homogeneous insulating materials is increased as the density, moisture content or mean temperature is increased.
Effect of ageing on heat conductivity of concrete.	A.S.H.V.E. lab. at U. S. Bureau of Mines.	A.S.H.V.E.	In progress.	

HEATING AND VENTILATING

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Absorption of solar radiation by roof or wall surface and effect of heat capacity on heat penetration.	A.S.H.V.E. lab. at U. S. Bureau of Mines.	A.S.H.V.E.	A.S.H V.E. Jour. sec. H.P.-A.C., Dec., 1929; in progress.	
Air leakage around weather-stripped windows.	U. of Wisconsin; G. L. Larson.	U. of Wisconsin.	In progress.	
Relation of air conditions to health.	Harvard School of Pub. Health; P. Drinker, C. P. Yaglou.	Co-op. with A.S.H.V.E.	In progress.	
Standardizing measurement of air flow through registers and grilles.	Armour Inst. of Tech.; Davies.	A.S.H.V.E.	A.S.H.V.E. Jour. sec. H.P.-A.C., Jan., 1930, progress report; in progress.	
Insulating effect of successive air spaces bounded by bright metallic surfaces.	L. W. Schad.	Westinghouse Elec. & Mfg. Co.	A.S.H.V.E. Jour. sec. H.P.-A.C., Nov., 1930; completed 1930.	
Absorption of noise in ventilating ducts.	U. of Wisconsin; G. L. Larson.	U. of Wisconsin.	A.S.H.V.E. Jour. sec. H.P.-A.C., Jan., 1931; completed 1930.	
Pressure difference across windows in relation to wind velocity.	U. of Michigan; J. E. Emswiler.	U. of Michigan.	A.S.H.V.E. Jour. sec. H.P.-A.C., Oct., 1929; completed 1929.	Pressure drop across window as high as 0.2 in. at 26 m.p.h. wind is reported.
Investigation of radiator performance.	Eng. Exp. Sta.; Purdue U.	Co-op.	In progress.	
Investigation of heating rooms with direct radiators equipped with inclosures.	U. of Illinois; A. C. Willard.	U. of Illinois.	Illinois Eng. Exp. Sta., Bul. 192; completed 1929.	
Fire hazard in warm air duct construction.	Washington U.; A. S. Landsdorf.	Washington U.	Completed 1930.	Found possible to set fire to wooden partition by overheated duct.
Investigation of relationship between quantity of steam required for heating and outside temperature expressed as degree-days.	Pennsylvania State College; W. H. Reish.	Pennsylvania State Col.	In progress.	
Tests on unit heaters to determine heating capacity, steam consumption and heat transfer coefficients.	Pennsylvania State College; P. J. Reber.	Pennsylvania State Col.	In progress.	
Heating and ventilating equipment and systems.	Catholic U.; George A. Weschler.	Catholic U.	In progress.	
Effect of radiator inclosures, shields and covers on heating effect of C. I radiator.	U. of Illinois.	Inst. of Boiler & Radiator Mfg.	U. of Illinois bulletins 169 & 192. third bulletin ready for publication; in progress.	
Heat transmission through wall board made of palmetto.	U. of Florida; J. Weil.	U. of Florida.	In progress.	
Design and calibration of heat-flow meters for building and insulating materials.	Pennsylvania State College; F. G. Heckler.	Pennsylvania State Col.	In progress.	
Application of heat-flow meters to measure heat flow through building walls.	Pennsylvania State College; F. G. Heckler.	Pennsylvania State Col.	In progress.	
Investigation of extended surface radiators and heat transfer from steam to air through metal walls.	Yale U.; E. H. Lockwood.	Yale U.		
Heating effect of radiators and study of method of rating them.	Pennsylvania State College; F. G. Heckler, E. R. Queer	Pennsylvania State Col.	In progress.	
Effect of different colored paint on heat emission from steam radiator.	Polytechnic Inst. of Brooklyn; P. R. Kolbe.	Polytechnic Institute of Brooklyn.	In progress.	
Effect of superheated steam on performance of unit heaters.	Pennsylvania State College; F. C. Stewart, P. J. Reber, R. D. Fellows.	Pennsylvania State Col.	In progress.	
Research for development of gas-fired unit heater.	Buffalo; R. D. Madison.	Buffalo Forge Co.	In progress.	
Efficiency and performance of solar heaters.	U. of Florida; J. R. Benton, A. G. Mullins.	U. of Florida.	In progress.	
Investigation of thermodynamic performance of operating cycles for refrigerating and air-conditioning equipment.	Yale U.; G. W. Colton.	Yale U.	In progress.	Includes study of stress distribution in certain machine elements.
Heat transfer in air-cooling apparatus.	Case School of Applied Science; G. L. Tune.	Co-op. with Cleveland Evaporator Co.	In progress	Study of effect of surface arrangement rate of flow of cooling fluid temperature difference and level.
Heat transfer in underground ducts, and ventilation of underground transformer vaults.	U. of Oklahoma.	Oklahoma Gas & Elec. Co.	In progress.	It is expected to establish constants that can be applied to any system.
Study of heat emitted by radiator from a steam-heated surface.	Cornell U.; W. M. Sawdon.	Cornell U.	In progress.	Radiation in vacuum and various air pressures to be investigated.

INTERNAL COMBUSTION

Investigation to determine oil characteristics that make it satisfactory for diesel engine fuel.	Naval Exp. Sta., Annapolis.	Co-op. with A.S.M.E.	In progress.	
Investigation to determine oil characteristics that make it satisfactory for diesel engine fuel.	Fairbanks, Morse & Co.; G. W. Zabel.	Co-op. with A.S.M.E.	In progress.	
Investigation to determine oil characteristics that make it satisfactory for diesel engine fuel.	Electric Boat Co.; E. Nibbs.	Co-op. with A.S.M.E.	In progress.	
Investigation to determine oil characteristics that make it satisfactory for diesel engine fuel.	Ingersoll-Rand Co.; Ralph Miller.	Co-op. with A.S.M.E.	In progress.	
Physical tests ofoil used in diesel engine fuel investigation.	Texas Oil Co., N. Y. C.	Co-op. with A.S.M.E.	In progress.	
Physical tests of oil used in diesel engine fuel investigation.	Standard Oil Co. N. J.	Co-op. with A.S.M.E.	In progress.	
Investigation of jet spray distribution as influenced by physical properties of the liquid fuel, the discharge velocity, the surrounding medium and proportional length.	Mechanical Lab., Technical U., Dresden; Dr. Ing. A. Haenlin.	Technical U., Dresden.		

INTERNAL COMBUSTION

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Effect of fuel analysis on combustion in diesel engine.	Cooper-Bessemer Corp.	Cooper-Bessemer Corp.		
Radiometric study of explosions in a gasoline engine.	U. of Illinois.	Eng. Exp. Sta. and Dept. of Mechanical Eng.	In progress.	To determine (1) the effect of various fuels and compression ratios on total radiation from flame, and (2) the distribution of energy throughout the spectrum of the flame.
Effect of physical properties of oil and orifice dimension on spray formation.	Pennsylvania State College; P. H. Schweitzer, K. J. De Juhasz.	Pennsylvania State College.	In progress.	This project has numerous subdivisions.
Investigation of pressure fluctuations in common-rail fuel-injection system.	Langley Memorial Aeronautical Lab.; A. M. Rothrock.	Langley Memorial Aeronautical Laboratory.	Oil Engine Power Conf., June, 1930.	
Experiments on supercharging the high-speed oil engine.	English univ. laboratories.	Inst. of Mech. Eng.	In progress.	The whole range of compression ratios (4.5 to 1) have been explored. A new cylinder capable of ratios up to 7 to 1 is now being used for the higher ratios.
Investigation on supercharger with gasoline engine.	Newark Col. of Eng.; A. C. Cullimore.	Newark Col. of Eng.	In progress.	
Investigation of supercharging.	Purdue U.; H. M. Jacklin, M. J. Zucrow.	Purdue U.	In progress.	
Constant-clearance vs. constant-compression operation of internal-combustion engine.	Purdue U.; H. M. Jacklin.	Purdue U.	In progress.	
Positive metering and distribution of gasoline in internal-combustion engines.	U. of Illinois; L. C. Price.	U. of Illinois.	In progress.	
Development of high-speed indicator for high-speed internal-combustion engines.	State College of Washington; E. B. Parker, O. E. Osburn.	State College of Washington.	In progress.	Method in use presents considerable difficulty, but seems to be free from speed limitations.
Study of indicator diagrams as a criterion of diesel engine performance.	Pennsylvania State College; G. I. Mitchell.	Pennsylvania State Col.	In progress.	
Service test on carbon formation in diesel engines.	Standard Oil Co. (Ind.); E. H. Hillman.	Standard Oil Co. (Ind.).	Petroleum Mechanical Eng. Oct., 1930.	
Torque and oil consumption tests on internal-combustion engines to determine relative merits of various lubricating oils.	U. S. Bureau of Mines, San Francisco, Calif; M. J. Gavin, Gustave Wade, A. L. Foster.	U. S. Bureau of Mines and American Petroleum Institute.	Bureau of Mines Tech. Paper 387; Completed 1930.	
Investigation of performance possible with dual-combustion diesel, and the factors that control injection characteristics of fuel sprays.	Langley Memorial Aeronautical Lab.	National Advisory Committee for Aeronautics.	In progress.	Results of tests have been applied to design.
Test of diesel engine governor characteristics and performance.	I. P. Morris Lab.	I. P. Morris & De La Vergne, Inc.	In progress.	
Study of internal friction in gasoline engines.	U. of Arkansas; L. C. Price.	U. of Arkansas.	In progress.	
A graphical method of determining ideal Otto and diesel cycle efficiencies, real mixture standard.	John Hopkins U. Graduate School in Mech. Eng.; J. C. Smallwood, Karl E. Schoenherr.	Johns Hopkins U.	In progress.	
Factors affecting crankcase design.	Purdue U.	Eng. Exp. Sta. Purdue U.	In progress.	
Investigation of scavenging action and propagation of combustion in precombustion chamber diesel engine.	Mech. Lab., Tech. U., Dresden; Dr. Ing. E. Schmidt.	Technical U., Dresden.	To be published in V.D.I., Spring, 1931; completed 1930.	
A theoretical investigation of flame front positions in the combustion chamber of internal-combustion engines.	Yale U. Dept. of Mech. Eng.; L. C. Lichty.	Yale U.	In progress.	The results will present a picture of the positions of the flame front for any given portion burned, compression ratio and heat loss during the process.
An investigation of detonation in internal-combustion engines in a cylinder head designed for detonation control.	Yale U. Dept. of Mech. Eng.; L. C. Lichty.	Yale U.	In progress.	An experimental investigation proceeding along a line almost diametrically opposite to trend of thought on the subject.
Investigation into effect of pressure in suction pipe on performance of oil engines.	Kings College, England.	Institution of Mechanical Engineers.	In progress.	
Temperature distribution and heat absorption by piston of 4-cycle diesel engine.	G. Emele, Karlsruhe, Germany.		In progress.	The non-cooled piston of a 4-cycle solid injection diesel engine is fitted with 22 thermo couples.
Development of thermo-couples with vacuum tube amplification to record instantaneous temperatures in high-speed internal combustion engine.	U. of North Carolina.	U. of North Carolina.	In progress.	
Measuring flow of highly viscous fluids through orifice plates in pipe lines.	Eng. Lab., Danzig Tech. U., Germany; H. Giese.	Danzig Tech. U.	In progress.	
Vibrations set up in high-pressure fuel piping in solid injection diesel engines.	A. E. G. Turbine Works, Germany; Prof. Schwerin.	A. E. G. Turbine Works.	Completed 1929.	Amplitude and character of vibration set up by pressure and velocity are calculated.
Measurement of pressure and velocity of fuel in engine nozzle.	College of Science & Eng., Waseda U., Japan; T. Suzuki.	Waseda U.	In progress.	
Influence of supercharging blower upon the efficiency of internal-combustion engine.	Mitsubishi Ship Bldg. & Eng. Works, Kobe, Japan; M. Segi.	Mitsubishi Ship Bldg. & Eng. Works.	In progress.	
Properties of cast Mg. piston for internal combustion engine.	Science Res. Inst. I.J.A., Japan; M. Honda.	Imperial Japanese Army.	In progress.	
Quantitative study on the scavenging in the two stroke internal-combustion engine.	Osaka College of Eng., Japan; T. Sasaki.	Osaka College of Eng.	In progress.	
Experimental study on two-stroke-cycle airless diesel engine.	Niigata Iron Works, Japan; S. Koto, S. Nakatani.	Niigata Iron Works.	In progress.	
High-speed lightweight airless diesel engine.	Ikegai Iron Works, Japan; T. Amai, S. Takagi.	Ikegai Iron Works.	In progress.	
Investigation on the fuel injection of diesel engine.	Tokushima Tech. College, Japan; I. Umeda.	Tokushima Tech. Col.	In progress.	
Study of the combustion in diesel engines.	Fukui Tech. College, Japan; T. Kanao.	Fukui Tech. College.	In progress.	
Airless injection of diesel engine.	Tokyo College of Eng., Japan; M. Kawada.	Tokyo College of Eng.	In progress.	
Characteristics of fuel valve and fuel pump of diesel engine.	Osaka College of Eng., Japan; T. Sasaki.	Osaka College of Eng.	In progress.	

LUBRICATION

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Accelerated ageing tests of turbine lubricating oil.	Pub. Serv. Elec. & Gas Co., Newark, N. J.	Pub. Serv. Elec. & Gas Co.		One hour of accelerated testing has same effect on oil as 100 hr. of operation in turbine.
Study on the sludging of turbine oils.	N. Y. Edison Co.; C. P. Menges.	N. Y. Edison system.	Completed 1929.	Data obtained from Funk sludging machine compared with performance in turbine.
Tests to show how steam turbine oils must be refined to render them oxidation-proof.	Brown Boveri & Co., Baden, Switzerland.	Brown Boveri & Co.	Completed 1930.	Chemical values such as acid and saponification are no criterion of emulsification properties of a turbine oil that has aged.
Service characteristics of diesel engine lubricating oil.	De Laval Separator Co.; A. E. Flowers, M. A. Dietrich.	De Laval Separator Co.	Trans. A.S.M.E. Vol. 52, No. 8, 1930.	
Purification of diesel engine lubricating oil.	De Laval Separator Co.; A. E. Flowers, M. A. Dietrich.	De Laval Separator Co.	Presented at National Oil & Gas power meeting of A.S.M.E., June 12 to 14, 1930.	
Study of the value of reclaimed oil for purpose of lubrication and best methods of reclamation.	Pennsylvania State College; J. W. Brandt.	Pennsylvania State Col.	In progress.	Lubricating properties of reclaimed oil being tested in Kingsburg machine.
Rectification of waste engine oil.	U. of Florida; Dr. T. R. Leigh.	U. of Florida.	In progress.	
Tests of lubricating oils to determine qualities, or tests which indicate service value.	Iowa State College of Agr. and Mech. Arts; G. W. Burke.	Iowa State College of Agr. and Mech. Arts.	In progress.	
Investigation of methods of determining oil-film temperatures.	Pennsylvania State College; L. J. Bradford.	Pennsylvania State Col.	In progress.	
Investigation of journal performance under conditions of perfect lubrication.	Pennsylvania State College; L. J. Bradford.	Pennsylvania State Col.	In progress.	
Friction of some lineshaft bearings.	U. of Wisconsin; E. R. Maurer, L. E. A. Kelso.	U. of Wisconsin.	In progress.	
Experimental determination of the distribution and thickness of oil film in flooded cylindrical bearing.	England; J. Goodman.		Proc. Inst. Civil Engineers Vol. 226, pt. 2, 1929, p. 242-288.	
Pressure distribution in oil films by means of electrical observation on large-scale models.	Albert Kingsbury.	Kingsbury Machine Wks. co-op. with A.S.M.E.	A.S.M.E. annual meeting 1930 Lubricating Research; in progress.	
Experimental test of hydrodynamic theory of lubrication.	Pennsylvania State College; L. J. Bradford.	A.S.M.E.	In progress.	
Determination of the distribution of pressure within the oil film of a sleeve bearing completely surrounding a journal.	Pennsylvania State College; L. J. Bradford.	Texas Company co-op.	Penn. State Eng. Exp. Sta. Bul. 39; in progress.	At journal speed of 320 f.p.m. unbroken oil film possible at 400 lb. per sq. in. projected area. For load of 100 lb. per sq. in. film thickness 0.0017 in.
Breakdown pressures of oil films under intermittent loads	Pennsylvania State College; L. J. Bradford.	Eng. Exp. Sta. Pennsylvania State College.	In progress.	
Finding the limiting thickness of oil film below which the properties of the lubricant are no longer the same as when tested in bulk.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Study of fundamental facts regarding effect of speed, load, temperature, and condition of bearing surface upon coefficient of friction under oiliness conditions.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Development of four types of oiliness machines and comparison of results from them.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Development of apparatus for extension of friction measurements to larger bearings.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Study of friction of small-sized bearings (up to 2¾ in.) in relation to mechanical design and other factors.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Experiments with the new Thoma oil-testing apparatus.	Hydraulic Inst., Munich Tech. U., Germany; Rolf Votlaender.	Munich Tech. U.	Completed.	This apparatus makes it feasible to compare directly the lubricating value of oils, which formerly could be determined only by application.
Bearing oils for integrating wattmeter.	Elec. Res. Inst. Tokyo Municipality, Japan; K. Adachi.	Elec. Res. Inst. Tokyo Municipality.	In progress.	
Determination of load-carrying capacity of commercially finished bearings.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Study of pressure distribution in oil film with variations of clearance and bearing length.	U. S. Bureau of Standards; M. D. Hersey.	A.S.M.E.	In progress.	
Design of machine and tests for determining effect of low temperatures of lubricants in the presence of refrigerants.	Pennsylvania State College; A. J. Wood.	Pennsylvania State Col.		
Comparative tests of lubricants for a rotary ammonia compressor.	Yale U.; E. J. Travanlar.		Published in Vol. 19, No. 2, Refrigerating Engineering, Feb., 1930.	
Lubrication of air compressor.	Harvard U.; A. E. Norton.	Harvard U.	In progress.	
Investigation of relation between thermal conductivity of lubricating oils and their lubricating value.	Brooklyn Edison Lab.	N. Y. Edison system.	Report with Lubrication Comm. of A.S.M.E.; completed.	
Thermal properties of petroleum and petroleum products.	U. S. Bureau of Standards.	American Petroleum Inst.	Thermal Properties of Petroleum Prod. Bureau of Standards Miscellaneous paper No. 97; in progress.	
Experiments on waste-packed bearings, ring oiling and forced lubrication.	Westinghouse Elec. & Mfg. Co.; G. B. Karelitz.	A.S.M.E.	In progress.	
Investigation of the oiliness of lubricating oils.	Hydraulisches Inst. der Tech. Hochschule, Munchen, Germany; Dr. Ing. D. Thoma.	Notgemeinschaft der Deutschen Wissenschaft.	By R. Voitlander, Mitteilungen des Hydraulischen Inst. der Tech. Hochschule Munchen, Vol. 3 and Vol. 4, 1931.	
Properties of lubricating oils at low temperatures.	U. of Berlin, Erk, Germany.	U. of Berlin.	In progress.	
Study of oil flash point testing apparatus.	U. of Berlin, Erk, Germany.	U. of Berlin.	In progress.	
Correlation of laboratory and service test data on turbine oils.	The Detroit Edison Co.	The Detroit Edison Co.	In progress.	

MATERIALS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Long-time creep tests of non-ferrous metals.	Naval Exp. Sta., Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.	In progress.	
Flow characteristics of iron-nickel and chromium alloys and steels at elevated temperatures.	U. S. Bureau of Standards; H. J. French.	U. S. Bureau of Standards.	Trans. A.S.M.E. F.S.P. 52-34.	
High-temperature creep tests of steel.	Polytechnic Inst. in Dresden; Dr. Ing. W. Gehler.	Polytechnic Inst. in Dresden.	In progress.	
Investigation of creep of metals at high temperature and bending fatigue.	Polytechnic Inst. Zurich, Switzerland.	Polytechnic Inst. Zurich.	In progress.	
Deformation of metals under prolonged loading.	U. of Birmingham; Prof. D. Hanson, M. A. Wheeler.	U. of Birmingham.	Progress report Inst. of Metals, March 12, 1931; in progress.	Work so far has been with aluminum and lead.
Investigation of fatigue and creep of metals at high temperatures.	Eng. & Met. Dept. of National Physical Lab., Teddington, England; Dr. H. J. Gough, H. J. Tapsell.	Eng. & Met. Dept. National Physical Lab.	In progress.	
High-temperature tension creep tests.	Metropolitan-Vickers Elec. Co., Manchester, England; R. W. Bailey.	Metropolitan-Vickers Elec. Co.	In progress.	
Investigation to find materials, equipment and operating methods for a 1,000 deg. superheater.	Detroit Edison Co.	Detroit Edison Co.	In Progress.	
Metals at elevated temperatures for use in power service. Investigation has included both ferrous and non-ferrous alloys.	U. of Michigan; Dr. C. L. Clark, Prof. A. E. White.	Detroit Edison Co.	In progress. Results reported in the following: Trans. A.S.M.E., Vol. 49, 1927 and Vol. 50, 1928; Trans. A.S.M.E., Vol. 51, 1929; Trans. A.S.S.T., p. 670, 1929; Dec. Meeting A.S.M.E., 1930; Trans. A.S.M.E., Vol. 52, 1930.	
Strength of ductile materials subjected to shear at elevated temperatures.	U. of Michigan; Franklin L. Everett	U. of Michigan, Dept. of Eng. Research.	In progress.	Supplements extensive work on tensile properties being done at Michigan by Prof. A. E. White and Dr. C. L. Clark.
Creep of metals under torsion and direct stress.	University Lab., England.	Institute of Mech. Eng.	In progress.	It has been established that for certain steels at temperatures as high as 500 deg. C. a stress can be found at which creep is less than 1/10⁸ in. per in. per hr. Evidence of intercrystalline corrosion at high temperatures has been found.
Fatigue of metals in torsion.	Polytechnic Inst. in Munich; Dr. Ing. L. Foppl.	Polytechnic Inst. in Munich.	In progress.	
Tests of fatigue and creep at high temperatures.	Kaiser Wilhelm Inst. for Steel Research at Dusseldorf.	Kaiser Wilhelm Inst. for Steel Research.	In progress.	
Creep test analysis at elevated temperature on materials suitable for large stationary and rotating structures.	U. of Michigan; Dr. C. L. Clark.	Allis-Chalmers Mfg. Co.	In progress.	
Intermittent creep tests of 500 lb. per sq. in. at 850 deg. F. for 2,000 hr. on forged and cast steels.	U. of Michigan; Dr. C. L. Clark.	Allis-Chalmers Mfg. Co.	In progress.	Test intended to more nearly reproduce working cycle of turbine.
Separate single-load creep tests for each load arrived at in increments of loading in the original creep tests.	U. of Michigan; Dr. C. L. Clark.	Allis-Chalmers Mfg. Co.	In progress.	For use in turbine parts at elevated temperatures.
Creep of steel at high temperatures.	U. S. Bureau of Standards.	Co-op. with joint Research Committee on this subject of American Soc. for Test. Materials and Amer. Soc. of Mech. Engrs.	Res. Paper of Bureau of Standards, 192, by H. J. French, W. Kahlbaum-A. A. Peterson; Bureau of Standards Res. Paper 270 Bureau of Standards Res. Paper 269.	This work has been under way for about 7 years. The details of test procedure and apparatus have been developed and data in the form of "Life" curves for a number of steels, both plain carbon and alloy steels have been published.
Comparative high-temperature short-time tension tests.	Tests conducted at laboratories of thirteen manufacturers.	Co-op. with A.S.M.E., A.S.T.M. Joint Research Com.	Progress report pub. A.S.T.M., Vol. 30, part 1, 1930; in progress.	
Long-time tension tests of steels at elevated temperatures.	Crane Co. Lab.; J. J. Kanter, L. W. Spring.	Co-op. with A.S.T.M and A.S.M.E.	Report pub. proceedings A.S.T.M. Vol. 30, part 1, 1930.	
Fatigue tests of steel at elevated temperatures.	U. of Illinois; H. F. Moore.	Joint Com. of A.S.M.E. and A.S.T.M.	In progress.	Test method has been developed and the testing of various steels is in progress.
Fatigue of metals.	U. S. Bureau of Standards; H. J. French.	A.S.T.M.	In progress.	
Steel at elevated temperatures.	Harvard U.; Albert Sauveur.	Harvard U.	In progress.	
Effect of temperature on properties of metals.	U. S. Bureau of Standards; H. J. French.	A.S.T.M.	In progress.	
Investigation of the torsional strength of metals at high temperature.	Polytechnic Inst. of Brooklyn, Dept. of Civil Eng.; P. R. Kolbe.	Polytechnic Inst. of Brooklyn.	In progress.	
Intercrystalline failure of metals.	Massachusetts Inst. of Tech.; Prof. W. S. Hutchenson.	Massachusetts Inst. of Tech.	In progress.	
Analysis of stresses in steel pipe flanges and fittings, preparatory to the adoption of standard proportions.	Yale U., Dept. of Mech. Eng.; E. O. Waters.	Yale U.	In progress.	
Fatigue tests.	State College of Washington.	State Col. of Washington.		
Performance of alloy-steel bolting materials at elevated temperatures (up to 800 deg. F.) under field conditions with laboratory checks.	Brooklyn Edison Co.	N. Y. Edison system.	In progress.	
Study of slip lines, strain lines and cracks in metals under repeated stress.	U. of Illinois; H. F. Moore.	U. of Illinois.	Bul. 208, U. of Illinois Eng. Exp. Sta.; completed 1930.	
To determine the general laws and phenomena of the fatigue of metals.	U. of Illinois.	Eng. Research Council, Eng. Foundation, General Elec. Co., Allis-Chalmers Co., Copper and Brass Assn.	In progress.	Twelve bulletins of the Eng. Exp. Sta. have been published and some theses of the U. of Illinois Graduate School have presented the results of this investigation.
Fatigue study.	Purdue U.	Eng. Exp. Sta., Purdue U.	In progress.	
Fatigue of metals at high-frequency reversals.	State Materials Testing Lab. at Berlin-Dahlem; Dr. K. Laute.	State Materials Testing Lab.	In progress.	

MATERIALS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Causes of embrittlement of structural steel, with particular reference to galvanizing embrittlement of transmission towers.	Battelle Memorial Inst.; Samuel Epstein.	Utilities Research Comm. and A.S.T.M.	A.S.T.M. bulletin, Dec., 1930, p. 7; in progress.	
Aging of iron and steel.	Harvard U.; Albert Sauveur.	Harvard U.	In progress.	
Development of fatigue-testing machine for bolt material.	Pub. Serv. Elec. & Gas Co., Newark, N. J.	Pub. Serv. Elec. & Gas Co.		
Study of the Ikeda (electrical resistance) short-time test for fatigue strength of metals.	U. of Illinois; H. F. Moore.	U. of Illinois.	Bulletin 205 U. of Illinois Eng. Exp. Sta.; completed 1929.	
Investigation to determine whether Shore scleroscope would show different rebounds for specimens under stress and specimens not under stress.	California Inst. of Tech.; Dept. of Mechanics.	Calif. Inst. of Tech.	In progress.	
X-ray examination of steel valve castings for 1,300-lb. central station service.	U. of Michigan; Dr. Lars Thomassen.	Houston Light. & Power Co.	In progress.	This method of inspection for heavy-duty valves seems desirable. When the thickness of metal to be examined exceeds 4 in. the use of gamma rays, on account of their greater penetrating power, should be considered.
Endurance properties of steel in steam.	General Electric Co.; T. S. Fuller.	General Electric Co.	A.I.M. & M.E., 1930, p. 280	
Effect of cold-working on stainless steels, especially torsional fatigue properties.	Naval Exp. Sta., Annapolis; Capt. H. R. Greenlee.	Naval Exp. Sta.	In progress.	
Nitriding of steel, with special study of effect of catalyzers and nitriding agents other than ammonia.	Pennsylvania State College; D. F. McFarland.	Pennsylvania State Col.	In progress.	
Study of the physical properties and behavior of materials for heavy plates for boiler drums.	U. of Michigan; A. E. White.	Detroit Edison Co.	In progress.	
Study of the physical properties and behavior of materials now used for turbine blades.	U. of Michigan; A. E. White.	Detroit Edison Co.	In progress.	
Research on turbine blade material.	Henry Souther Eng. Co.	Two clients.	In progress.	
Endurance properties of steel in steam.	General Electric Co.; T. S. Fuller.	General Electric Co.	Amer. Inst. Min. & Mech. Engrs., 1930, p. 280.	
Long-time tests of pipe-line flange bolts in service.	Plants of the sponsor and at U. of Michigan; Prof. William P. Wood.	Detroit Edison Co.	Started in 1923 and the bolts were reported upon at the end of the following periods: 6 months, 1 year, 2 years, 4 years (April, 1928). A.S.M.E., Nov. 30, 1925 by Wm. P. Wood	For the temperatures in question, about 750 deg. F., the carbon content for bolting steel ranging from about 0.2 per cent up to 0.45 per cent will yield the best combination of tensile strength and ductility in either the heat-treated or non-heat-treated condition.
Perfecting magnetic iron.	Westinghouse Elec. & Mfg. Co.; Dr. T. D. Yensen.	Westinghouse Elec. & Mfg. Co.	American Electro-Chemical Society, 1929.	
Experimental work on special steels covering forging, heat-treatment, physical testing and coefficient of expansion.	Allis-Chalmers Mfg. Co.	Allis-Chalmers Mfg. Co.	In progress.	
Metals for gaskets.	U. of Michigan; A. E. White.	U. of Michigan.	In progress.	
Determine physical properties of A.S.T.M. Grades A and B seamless steel boiler pipes at 850 deg. F.	U. of Michigan; A. E. White, C. L. Clark.	Detroit Edison Co.	In progress.	
Internal-combustion engine valve materials.	General Motors Lab.; Dr. F. O. Clements.		In progress.	
Valve and valve seat materials and design for diesel engines.	Cooper Bessemer Corp.	Cooper Bessemer Corp.		
Study of action of a series of coal ash slags on a series of special boiler furnace refractories.	Battelle Memorial Inst.; Dr. H. E. Simpson.	Co-op. with research com. of A.S.M.E.	In progress.	Determination by examination under a petrographic microscope of the temperature range above which rapid attack of refractory by slag occurs.
Refractories service survey in boiler furnaces.	Various power plants and U. S. Bureau of Mines, Pittsburgh Exp. Sta.; P. Nicholls.	U. S. Bureau of Mines and A.S.M.E.	U. S. Bureau of Mines Bul. 344; completed 1931.	
Abrasion of refractories at high temperatures.	Pennsylvania State College; J. B. Shaw.	Pennsylvania State Col.	In progress.	
Study of crystalline compounds formed in slags on boiler furnace refractories.	Bureau of Standards at Columbus, Ohio; T. A. Klinefelter.	Co-op. with A.S.M.E. and U. of Illinois.	A.S.M.E. Trans. Vol. 51, No. 22, 1929; in progress.	
To determine manner in which destruction of firebrick proceeds in firebox of power plant boilers.	U. of Illinois; Dept. of Ceramic Eng.	Co-op. with A.S.M.E.	In progress.	
Development of slagging test for boiler furnace refractory.	U. of Illinois Eng. Exp. Sta.; R. K. Hursh.	Co-op. with A.S.M.E.	Trans. A.S.M.E. Vol. 51, No. 22, 1929.	Satisfactory test has been developed.
Investigation to determine the reaction and equilibria that underly refractory failures in boiler furnaces.	U. S. Bureau of Standards; T. A. Klinefelter, E. P. Rexford.	Co-op. with A.S.M.E.	In progress.	
An X-ray study of firebrick.	U. of Illinois; E. R. Westman.	U. of Illinois.	Bul. 193 Eng. Exp. Sta., U. of Illinois; completed 1929.	
Analytical standards of chrome magnesite and silica materials used in refractories.	U. S. Bureau of Standards and 12 industrial and private laboratories.	A.S.T.M.	In progress.	
Cold-crushing strength of firebrick.	Ohio State U.; H. K. Nutra.	Eng. Exp. Sta.	Eng. Exp. Sta., Bul. 54; completed 1930.	
Making high-temperature cements from scrap refractories.	Iowa State College of Agr. and Mech. Arts; D. A. Moulton.	Iowa State College of Agr. and Mech. Arts.	In progress.	
Utilization of pulverized-fuel ash.	Bound Brook, N. J., Washington, D. C., and Frankfurt, A. M., Germany.	Research Corp.	In progress.	
Disposal of coal ash when burning pulverized coal.	Armour Inst. of Tech.	Armour Inst. of Tech.	In progress.	
Investigate possibilities of commercial utilization of pulverized fuel ash from the Trenton Channel plant.	U. of Michigan and in the plants of the sponsor; A. H. White.	Detroit Edison Co.	Completed Jan., 1931.	The results obtained are promising.
An investigation to develop some use for pulverized coal ash.	Detroit Edison Co.	Detroit Edison Co.	In progress.	
Removal of ash as molton slag from pulverized coal furnaces.	U. S. Bureau of Mines, Pittsburgh Exp. Sta. and various power plants; P. Nicholls.	U. S. Bureau of Mines and Am. Soc. Mech. Engrs.	Trans. A.S.M.E., Vol. 51, No. 22, Sept.-Dec., 1929, pp. 399-413.	

MATERIALS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Study of some factors in removal of ash as molten slag from pulverized coal furnaces.	R. A. Sherman.	A.S.M.E. refractory research.	A.S.M.E. Fuels & Steam Power Sec. Trans. Sept. and Dec., 1929.	
Accelerated aging tests of paint materials.	Pub. Serv. Elec. & Gas Co., Newark, N. J.	Pub. Serv. Elec. & Gas Co.	In progress.	
Tests on belting.	Polytechnic Inst. of Dresden, Germany; Prof. K. Kutzbach.	Polytechnic Inst. of Dresden.	In progress.	
Durability of belt lacings and fastenings.	Kansas State Agr. College; W. W. Carlson, G. A. Sellers.	Kansas State Agr. Col.	In progress.	
Stretch in rubber transmission belting.	B. F. Goodrich Co.; C. W. Staache.	B. F. Goodrich Co.	A.S.T.M. Proc. Vol. 30, Part II.	Investigations were made to determine proper amount of inelastic stretch to remove during manufacture.
Service tests on rubber belts.	Goodyear Tire & Rubber Co.; E. G. Kimmick.	Goodyear Tire & Rubber Co.	A.S.T.M. Proc., Vol. 30, Part II.	Unit tension, number of plies and pulley diameters are important factors in ply separation.
Accelerated life tests of several brands of rubber coal conveyor belting.	Detroit Edison Co.	Detroit Edison Co.	1929.	
Research on bearing metals	Battelle Memorial Inst.; H. W. Gillett.	Battelle Memorial Inst.	In progress.	
Properties of babbitt metal.	U. S. Bureau of Standards; H. J. French.	A.S.T.M.	In progress.	
Study of babbitt materials and design.	Cooper-Bessemer Corp.	Cooper-Bessemer Corp.		

STEAM PRIME MOVERS

Study of the flow of heat in turbine rotors of large mass to determine value of stresses resulting from temperature differentials.	South Philadelphia Works; T.C.Rathbone, B.Anoschenko.	Westinghouse Elec. & Mfg. Co.	Completed 1929.	Tests show the assumption that when a cold body of steel is suddenly exposed to hot steam the skin of the metal is at once raised to the temperature of the steam is a fallacy. Only moderate stresses are set up.
To determine the effect of blade pitch on the efficiency of reaction blading.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	
To determine the effect of surface finish on the efficiency of reaction blading.	South Philadelphia Works; F. Dollin.	Westinghouse Elec. & Mfg. Co.	Completed 1930.	It appears that there is a small but real variation in efficiency with variation of the smoothness of the blade surface.
To determine the effect of lashing wire on the efficiency of reaction blading.	South Philadelphia Works; F. Dollin.	Westinghouse Elec. & Mfg. Co.	Completed 1930.	The probable loss of efficiency caused by lashing wires was computed on the basis of aerodynamic theory, and tests show the actual loss comparable to, but rather larger than, the calculated loss. This is as had been expected.
To find means of improving the efficiency of two-row impulse elements.	South Philadelphia Works; F. Dollin.	Westinghouse Elec. & Mfg. Co.	Completed 1930.	It has been found that an improvement in efficiency may be obtained by making the blade heights shorter than those theoretically required. The selections of blade angles have been improved, but no specific conclusions can be stated.
To investigate various forms of nozzles, both convergent and convergent-divergent.	South Philadelphia Works; F. Dollin.	Westinghouse Elec. & Mfg. Co.	In progress.	The results of the investigation to date have made possible the development of improved practical nozzle shapes for a wide range of application. A number of maxims governing the design of nozzles have been deduced.
To investigate the distribution of steam flow in the exhaust chambers of large turbines and to study the influence of various baffle arrangements on over-all turbine efficiency.	South Philadelphia Works; T. C. Rathbone.	Westinghouse Elec. & Mfg. Co.	Completed 1930.	Large variations in velocity were found and data obtained by which conditions can be improved in future installations.
To investigate the existence and magnitude of electro-static charges between spindle and cylinder blades due to steam friction.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	A small potential difference was found, which appears to vary with change of load, but to date no conclusion has been reached concerning its possible influence on blade corrosion.
To perfect a magnetic means for detecting transverse and longitudinal cracks in blade material.	South Philadelphia Works; J. Ormondroyd, B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	Completed 1930.	Such a device has been perfected and tested and has been introduced as a standard feature of the blade-manufacturing process.
To determine the influence of various types and methods of chromium plating on the longevity of blades subjected to vibration.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	
To determine the stresses in a blade-lashing system.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	
To determine the influence of various lashing systems on the damping of blade vibration.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	Conclusion to date is that by introduction of an additional wire, with very slight change in total stresses of the blade, a considerable damping effect may be obtained, resulting in halving amplitude of vibration at the resonant frequency.
To determine the influence of lashing wire system on reduction of blade stresses due to steam load.	South Philadelphia Works; B. Anoschenko.	Westinghouse Elec. & Mfg. Co.	In progress.	Results so far obtained show that proper lashing may reduce blade stresses to approximately half of those in the unlashed blade.
Carbon dioxide as a preventive of fire in turbine generators.	Duquesne Light Co.	Duquesne Light Co.		
Development of instrument to record mean amplitude of turbine vibrations.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Study of spring foundations for large turbine units.	Detroit Edison Co.	Detroit Edison Co.		

STEAM PRIME MOVERS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Low-cost peak-load capacity with bleeder turbines.	Johns Hopkins U; Warren Viessman.	A. G. Christie.	Presented before Metropolitan A.S.M.E. Feb., 1930; recently completed.	Study indicated that the peak-load capacity of the steam turbines could be increased by cutting off bleeder heaters at the time of peak load, and that the boiler house efficiency could be maintained during this period by furnishing hot water from accumulators connected to the bleeder system.
Possibilities in increasing engine economy.	Eng. Exp. Sta. Purdue U.	Purdue U.	In progress.	
Reaction gas turbine.	Harvard U.; L. S. Marks.	Harvard U.	In progress.	
Reduction of cylinder condensation in piston steam engines.	Purdue U.; G. H. Shepard.	Purdue U.	In progress.	
Investigation of transverse vibration of turbine wheels with wheel at rest and rotating.	Fraser & Chalmers Eng. Wks., Erith, Kent, England.	Fraser & Chalmers Eng. Wks.	In progress.	
Investigation of vibration of turbine blades with blades at rest and blades on rotating wheel.	Fraser & Chalmers Eng. Wks., Erith, Kent, England.	Fraser & Chalmers Eng. Wks.	In progress.	
Investigation of efficiency of complete turbine stage.	Fraser & Chalmers Eng. Wks., Erith, Kent, England.	Fraser & Chalmers Eng. Wks.	In progress.	
Tests on steam consumption of back-pressure and bleeder turbines (flow coefficient of nozzles with sound speed).	Engine lab. of the Tech. U., Charlottenburg (Berlin); Prof. Josse.	Tech. U. Charlottenburg	Archiv für Wärmewirtschaft, 1929; Heft 5 (VDI) Jan., 1929.	
Experimental data on flow through nozzle and elbow as a basis for steam turbine nozzle design.	Munich; G. Kerkowitz.			The efficiency increases with the rate of flow. Rate of flow has little influence on the transformation of energy.
Investigation of the mechanics of plate rotors for turbine-generators.	Westinghouse Elec. & Mfg. Co. E. Pittsburgh; J. P. Den Hartog.	Westinghouse Elec. & Mfg. Co.	Trans. A.S.M.E., 1929, Vol. 51.	Methods of calculation of the plate rotors have been evolved and experiments have been carried out to place the design of this apparatus on a rational basis.
Stresses and changes in shape of annular-shaped membranes.	A. E. G. Turbine Works, Germany; Prof. Schwerin.	A. E. G. Turbine Works.	Completed 1929.	Experimental determination of stresses in membranes, such as diaphragms, used as a part of turbine or engine governors.
Experimental determination of the practical average gripping strength of turbine rotor shroud rings on the turbine blades.	A. E. G. Turbine Works, Germany; Kirchberg.	A. E. G. Turbine Works.	Completed 1930.	Vibrations were artificially set up to determine the efficiency of the rivetted connection of the turbine blades to the shroud ring.
Steam turbine governor performance during system disturbances.	General Electric Co.; Buell, Caughey, Hunter, Marquis.	General Electric Co. and American Gas & Elec. Co.	A.I.E.E. Trans., March, 1931.	

SMOKE AND DUST ABATEMENT

Studies of fly ash from boilers and dust from coal-pulverizing for the purpose of minimizing both.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Fly-ash and sulphur-fume elimination from flue gases.	Commonwealth Edison Co.	Commonwealth Edison Co.	In progress.	Spray process investigated removes over 90 per cent of ash from gas but ineffective for sulphur.
Elimination of sulphur fumes from combustion gases.	Research Corp., Washington, D. C.	Research Corp.	In progress.	
Dust-collection tests on coal-pulverizing mills and powdered coal furnaces.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		Tests on quantity of dust and means of reducing discharge.
Methods of determining dust in air.	U. of Minnesota; F. B. Rowley, F. A. Morris, John Beal.	U. of Minnesota.	In progress.	
Photographic recording of smoke.	St. Louis; V. J. Azbe.	Citizens Smoke Abatement League of St. Louis.	Mech. Engrg., June, 1930.	
Test on flue-dust washer at various gas velocities.	W. S. Barstow & Co., Inc.	Binghamton Light, Heat & Power Co.	Completed 1929.	Computed eff. of washer is comparative at the various velocities, best eff. at 450 f.p.m. or lower.
Study of cinder, soot and ash deposits in the city of Kalamazoo.	Kalamazoo, Mich.; C. H. Fessenden.	City of Kalamazoo, Mich.	In progress.	
Investigation of elimination of cinders from stacks by improved collecting device.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Determination of efficiency of bleeder type Cottrell precipitation on stoker and pulverized-fuel-fired boilers.	Sherman Creek station, New York.	United Electric Light & Power Co.	In progress.	
Method of removing harmful and corrosive constituents from the flue gases of a power plant.	U. of Illinois Eng. Exp. Sta.	Co-op. with Utilities Research Comm.	In progress.	Investigation is an outgrowth of an investigation of the prevention of corrosion by flue gases.
Removal of sulphur compounds from coal gas by means of alkaline arsenite solution and recovery of byproducts.	Armour Inst. of Tech., Chicago; H. McCormack.	Armour Inst. of Tech.	In progress.	
Investigation of dry and wet centrifugal scrubbers for use in boiler plants and chemical processes.	Buffalo Forge Co.; R. T. Thornton.	Buffalo Forge Co.		
Nine years of smoke-abatement work at Salt Lake City	U. S. Bureau of Mines.	U. S. Bureau of Mines.	R. I. 3001, April, 1930, by Austin Gudmundsen.	
Study on flue-dust collectors and density of fly dust on surrounding terrain.	W. S. Barstow & Co. Inc.	Binghamton Light, Heat & Power Co.	Completed 1929.	
Study of atmospheric contamination, its sources as relating to fuel combustion, its effect, both mechanical and chemical.	Stevens Institute; E. H. Whitlock, A. C. Stern.	Stevens Institute with stations in Hoboken, and Central Park and Whitehall Building, N. Y. C.	In progress.	Several forms of apparatus for testing quantity and size of particles are ready for experimental use.
Measurement of atmospheric dust.	Washington U.	Washington U.	In progress.	
Quantitative measurement of atmospheric smoke pollution.	Washington U.	Washington U.	In progress.	
Effects of dust fumes and smoke on men and animals.	Harvard U.; Philip Drinker.	Harvard U.	In progress.	

SMOKE AND DUST ABATEMENT

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Tests to determine weight of solids carried by flue gas from under-feed stoker, and loss of efficiency due to combustible in soot.	Pub. Serv. Elec. & Gas Co.	Pub. Serv. Elec. & Gas Co.	N.E.L.A. Prime Mover Report on Boiler and Turbine Instruments, 1930.	
Development of method of eliminating sulphur fumes.	Grove Road Power Plant, England.	London Power Co.	Report presented to British Minister of Transport; *Power*, Dec. 30, 1930.	Sulphur elimination equipment installed at Battersea station based on this investigation.
Observation of atmospheric pollution.	Chief Cities of England.	Dept. of Scientific & Industrial Research of Board of Trade.	In progress.	
Elimination of dust from gas by cyclones, bag filters and centrifugal separation.	Fraser & Chalmers Eng. Wks., Erith, Kent, England.	Fraser & Chalmers Eng. Wks., Erith, England.	In progress.	
Dust recovery from vapor or smoke with distillate production (results of a large plant).	Power plant Boehlen, near Leipzig; Prof. Josse.	Tech. U., Charlottenburg	Zeitschrift des Vereins Deutscher Ingenieure, 1930.	
Analysis of apparatus for measuring dust and methods of dust measurement.	Potsdam U., Germany; Suering.	Potsdam U.	In progress.	
Measurements of filter cloths for dust catching.	Berlin U., Germany; R. Meldan.	Berlin U.	In progress.	
Research on separation of dust from gases by cyclones.	Dresden, Germany; P. Rosin.	Committee on fuel of the Reichskohlenrat.	In progress.	
Wet separation of dust from gas.	Tech. U. of Berlin, Charlottenburg; W. Wernicke.	Tech. U. of Berlin.	In progress.	
Research on dust filtering.	Exp. Sta. of Tech. U. of Berlin-Charlottenburg; R. Meldan.	Committee on fuel of the Reichskohlenrat.	Completed 1930.	
Research on the settling of dust in large chambers.	Germany; P. Rosin.	Committee on fuel of the Reichskohlenrat.	In progress.	
Collection of data on the settling of dust in flues of boilers and stacks and the distances dust is carried in open air.	Hannover and Dresden, Germany; R. Meldan, F. Schulte, E. Arend, E. Rammler.	Committee on fuel of the Reichskohlenrat.	Verein zur Ueberwachung der Kraftwertwachungs der Ruhrzechen, Essen, and Dampfkessel Ueberwachungs-Verein, Hannover; in progress.	
Theory and technical development of flue-dust separation.	E. Heitmann.	Committee on fuel of the Reichskohlenrat.	Berechtfolgen des Kohlenstaubausschusses des Reichskohlenrates No. 20; completed 1929.	
Development of a method and instruments for tapping off and measuring flue dust.	Germany; E. Zimmerman.	Committee on fuel of the Reichskohlenrat and Berliner Elektrizitaetswerke A. G.	Z.V.D.I., April, 1931; completed 1930.	

THERMAL

Measurement of latent heat of steam from atmospheric pressure to highest attainable pressure.	U. S. Bureau of Standards; N. S. Osborne.	Co-op. with A.S.M.E.	Mech. Eng. 1921 to 1931; in progress.	
Investigation of Joule-Thomson cooling effect in superheated steam.	Harvard U.; Dr. H. N. Davis, R. V. Kleinschmidt.	A.S.M.E.	Mech. Eng.; completed 1928.	
Measurements on the pressure-temperature volume relation of the liquid, saturated vapor and superheated steam, together with density of liquid water.	Massachusetts Inst. of Tech.; Dr. F. G. Keyes.	A.S.M.E.	In progress.	
Determination of specific heat of water.	U. S. Bureau of Standards; N. S. Osborne.	Co-op. with A.S.M.E.	Mech. Eng., 1921 to 1931; in progress.	
Dissociation of water in steel tubes at high temperatures and pressures.	Detroit Edison Co.; C. H. Fellows.	Detroit Edison Co.	Jour. Am. Waterworks Assn.; completed 1929.	Presence of hydrogen in steam established, greater in superheated steam than in saturated steam.
Evaporation and liquid superheat.	Mech. Lab. Tech. U., Dresden; Dr. Ing. F. Bosnjakovic.	Mech. Lab., Tech. U., Dresden.	In progress.	This is an investigation of the factors causing liquid temperature to be higher than steam temperature.
Study of calorimetric methods of moisture determination in high-pressure steam lines.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Determination of the quality of wet steam by means of the electric steam calorimeter, invented by C. C. Thomas.	California Inst. of Tech., Dept. of Mech. Eng.	California Inst. of Tech. co-op. with power companies interested in high-pressure steam plants.	In progress.	
Researches on evaporation.	U. of Michigan; Prof. W. L. Badger, W. L. McCabe.	Swenson Evaporator Co.	In progress.	The forced-circulation type of evaporator, developed in this laboratory, offers considerable promise as a power plant make-up evaporator that will prepare water of very high purity. Active work on the adaptation of this apparatus for power plant work is going forward.
Investigation of radiating properties of carbon and some of the products of combustion.	Yale U.	Yale U.	In progress.	The start of an elaborate program in the field of combustion.
Intensity of radiation from boiler surfaces—development of instrument and method.	State U. of Iowa; H. O. Croft.	State U. of Iowa.	In progress.	
Development of method for determining efficiency of different parts of condensers.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Effect of stage heating on thermal efficiency.	N. Y. Edison system.	N. Y. Edison system.	In progress.	Progress report indicate theoretical savings are not obtainable in practice.
Solution cycles. These cycles are high-temperature, low-pressure cycles for the economic conversion of heat into work.	U. of Michigan; W. H. Sellew.	Various.	In progress.	The results obtained so far seem to offer considerable promise.

THERMAL

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Reheating of steam by steam at 1,400 lb. pressure.	Consolidated Safety Valve Co.	Elec. Bond & Share Co.		Heat transfer of 50 B.t.u. per sq. ft. per hr. per deg. temperature difference indicated.
Study of heat gradients and flue gas temperatures in concrete stack.	Texas Power & Light, Trinidad sta.	Texas Power & Light.		
Specific volumes of water vapor up to 270 atm. and 400 deg. C.	I. G. Farbenindustrie.	World Power Steam Table Committee.		
Heat of evaporation of water and specific volumes of saturated steam up to 100.7 atm. pressure and 310 deg. C. temperature.	Reichsanstallt, Berlin; M. Jacob, W. Fritz.		Completed 1930.	
Specific heats of superheated steam up to 370 deg. C. and 200 atm. pressure.	Munich Lab. of German Physics; W. Koch.	Munich Lab. of German Physics.	In progress.	Steam is generated electrically. A predetermined amount of heat is added in an adiabatic calorimeter. Maximum value of specific heat 368.7 deg. C. 4.2 kcal per Kg. at 200 atm.
Analysis of thermal equation of steam in critical-pressure zone. Derivation of formula involving specific heat at constant pressure and constant volume.	Fritz Naumann.	V.D.I. Karlsruhe.	Completed 1930.	Discussion by Steier of Heidelberg brought out the contention that the heat content of water at high pressures is a function of the pressure.
Properties of steam at high pressure.	Lab. at Moravska Ostrava Masarykava Akademie, Czechoslovakia; Dr. Ing. J. Havlicek.		Mech. Eng. 1929; Eng., 1931, p. 311.	
Specific heats of steam at pressures up to 250 atm.	Munich U., Germany; Knoblauch.	Munich U.	In progress.	
Heat given up by condensation of saturated and superheated steam.	Berlin U., Germany; M. Jacob.		In progress.	
Thermal properties of methylamin (CH_3NH_2) as a refrigerating medium.	Karlsruhe, Germany; R. Plank.		Completed 1930.	The use of calcium with methylamin is not advisable due to incomplete saturation at absorber temperature and the carrying over of the light precipitate formed in the generator. Lithium chloride methylamin is more satisfactory.
Temperature distribution and turbulence created by the condensation of superheated steam in a pipe.	Berlin U. Germany; M. Jacob, S. Erk, H. Eck.	Berlin U.	Completed 1930.	
Photographic demonstration of atmospheric convection swirls in the vicinity of cooling bodies.	Karlsruhe, Germany; E. Schmidt.	Com. on Heat Research, V.D.I.		
Investigation of condensation of steam in film and drop forms.	Danzig, U., Germany; E. Schmidt, W. Schurig, W. Sellschopp.	Danzig U.	Completed 1930.	
Investigation of endothermal and exothermal properties of different types of bodies.	Stuttgart, Germany; Reiher.	Stuttgart U.	In progress.	
Investigation of thermal properties of mixed fluids.	Munich U., Germany; Prof. Knoblauch.	Munich U.	In progress.	
Relation of specific heats of different gases (air, nitrogen, CO_2 and H_2O) at temperatures up to 1,350 deg. C.	Henning and Justi.			Based on theory of atomic wave motion in molecular structure. Results coincided with those obtained at Reichsantalt during 1905 and 1907.
Analogy and relation of effects observed by the condensation of superheated steam and the turbulence problem.	Karlsruhe, Germany; M. Jacob, S. Erk and H. Eck.	Com. on Heat Research V.D.I.		
Investigation of diphenyl thermal properties.	Georgia School of Tech.; John Chipman.	Georgia School of Tech.	Ind. & Eng. Chem., Vol. 21, p. 1106 (1929); Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.; completed.	This investigation embraced the determination of the vapor pressure relations and the latent heat of vaporization.
Investigation of diphenyl thermal properties.	Research Lab. of Applied Chem. Massachusetts Inst. of Tech.; H. O. Forrest.	Swann Chemical Co.	Ind. & Eng. Chem., Vol. 23, No. 1, p. 37-39 (1931); Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.	Determination of specific heat of the liquid by two independent methods.
Investigation of diphenyl thermal properties.	U. of Michigan; Prof. W. L. Badger.	Swann Chemical Co.	Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.; completed.	This investigation embraced the determination of the specific heat of the liquid at temperatures below the boiling point under atmospheric pressure.
Investigation of diphenyl thermal properties.	U. of Michigan; J. M. Cork.	Swann Chemical Co.	Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.; completed.	This investigation embraced the determination of the vapor pressure, temperature relations and the determination of the specific heat of the liquid and the latent heat of vaporization.
Determination of the physical properties of diphenyl.	U. of Michigan; J. M. Cork.	Swann Chemical Co.	Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.; completed.	This investigation embraced the determination of the densities in both the liquid and vapor state.
Determination of the physical properties of diphenyl.	Georgia School of Tech.; John Chipman.	Georgia School of Tech.	Ind. & Eng. Chem., Vol. 21, p. 1106 (1929); Bul., Physical Prop. of Diphenyl, published by Swann Chemical Co.; completed.	This investigation embraced the determination of the densities in both the liquid and vapor state.
Heat-transfer properties of diphenyl.	U. of Michigan; Prof. W. L. Badger.	Swenson Evaporator Co.	Ind. & Eng. Chem., Vol. 22, p. 700 (1930); blueprint of film-transfer curve, available from Swann Chemical Co.; in progress.	Reports the results of research work to determine the film coefficient between condensing diphenyl vapor and a vertical tube.
Corrosive properties of diphenyl.	Swann Research, Inc.; J. N. Carothers.	Swann Chemical Co.	Temporarily suspended.	Has shown that diphenyl does not attack and is not attacked by metals ordinarily used in the construction of mechanical equipment.

WATER POWER

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Development of high-speed runners for use with fixed- and adjustable-vane type water turbines. Includes cavitation testing.	I. P. Morris hydraulic lab., Shawinigan Water & Power Co. Lab., Safe Harbor Water Power Corp. Lab.	I. P. Morris & De La Vergne Inc.	In progress.	
Study of serious vibrations in high-head francis turbine installations.	Santeetlah Power House, Tapaco, Tenn.; J. P. Growdon, J. P. Den Hartog, G. A. Jessop.	Aluminum Co. of America and S. Morgan Smith Co.	A.S.M.E. Hyd. 51-13, Pages 101-110; completed 1929.	To avoid objectional vibration phenomena in penstocks and francis turbines, the number of buckets on the runner should never be one less than the number of guide vanes.
Tests of hydraulic turbine governor characteristics and performance.	I. P. Morris Lab.	I. P. Morris & De La Vergne Inc.	Completed 1930.	
Guide vane and head-gate leakage tests on Holtwood hydro units.	Pennsylvania Water & Power Co., Baltimore.	Pennsylvania Water & Power Co.		
Frazil ice prevention tests on hydro units.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.	In progress.	Three methods of combating frazil ice on large hydro units are being tried with an actual installation of each on one unit; (1) introducing steam around lower distributor ring below guide vanes, (2) electrical heating of guide vanes from iron losses introduced by induction from a 60-cycle conductor passing through all the vanes, and (3) electrical heating of intake screens in gate house.
Investigation on water turbines to explain cavitation phenomenon.	Hydraulic Lab., Technical U., Dresden; A. Reinhardt.	Dresden Technical U.	In progress.	
Model test Rock Island hydro development.	Worcester Polytechnic Inst.	Stone & Webster Eng. Inc.	In progress.	
Penstock Intake model tests.	Worcester Polytechnic Inst.	Elec. Bond & Share Co.	Completed 1929.	
Dam and spillway model tests.	Worcester Polytechnic Inst.	Rumford Falls Power Co.	Completed 1929.	
Spier Falls development tests.	Worcester Polytechnic Inst.	N. Y. Light & Power Co.	Completed 1929.	
Model test Fifteen Mile Falls lower development.	Worcester Polytechnic Inst.	New England Power Co.	Completed 1929.	
Development of Fifteen Mile Falls draft tube.	S. Morgan Smith Co., York, Pa.	New England Power Co.	Completed 1929.	
Temperature studies in an arch dam.	U. of Alabama.	U. of Alabama.	In progress.	Thermocouples were set in the concrete at time of construction and readings taken.
Model tests on Hoover dam.	U. S. Bureau of Reclamation.	Co-op. with arch dam com. of Engineering Foundation.	In progress.	A model of plaster of paris diluted with Celite to reduce modulus of elasticity is under construction.
Model study of gravity dams arched downstream.	U. of Iowa; B. J. Lambert.	U. of Iowa.	A.S.C.E. Vol. 57, No. 3.	
Cushion pools for spillways. Studies on model of Calderwood spillway with 180-ft. vertical drop; 200,000 sec. ft. capacity.	Carnegie Inst. of Tech.; R. F. Ewald.	Aluminum Co. of America.	Completed 1930; paper under preparation.	A submerged jet deflector increases the efficiency of a cushion pool.
Tests on rubber models of Calderwood and compensated arch dams.	Research Lab. of Aluminum Co. of America, New Kensington, Pa.; R. L. Templin.	Aluminum Co. of America.	Proceedings A.S.C.E., Feb., 1931, pages 359-376; in progress.	
Tests of celluloid models of Stevenson creek dam.	Princeton U.; Prof. G. E. Briggs.	Princeton U.		
Hydrostatic tests on dished heads for penstock gates, and development of suitable welding procedure.	Research Lab. of Aluminum Co. of America and Leetsdale shops of Riter Conley Mfg. (now McClintic Marshall Co.); R. L. Templin, A. J. Ackerman.	Aluminum Co. of America and Riter Conley Mfg. Co.	Completed 1929; paper under preparation.	Peening of welds relieves residua strains in a structure. Welded vessels of rigid shape must be annealed.
Stresses in large penstocks and pipe lines. Tests on model pipe line, Design and spacing of saddles.	Research Lab. of Aluminum Co. of America, New Kensington, Pa.; R. L. Templin.	Aluminum Co. of America.	In progress.	
Strain and deflection measurements on 200-ft.-high arch dam.	Calderwood dam, Tennessee; R. L. Templin.	Aluminum Co. of America.	In progress.	
Observations on Bull Run dam.	D. C. Henny.	Eng. Foundation.		
Tests on concrete model of Gebson arch dam.	U. of Colorado; J. L. Savage.	Co-op. with U. S. Bureau of Reclamation and Eng. Foundation.	Completed 1929.	
Observation of Shaver Lake dam.	Southern California Edison Co.; H. W. Dennis.	Eng. Foundation.		
Full-size tests on 27.5 x 40 ft. spillway openings by means of Pitot tube traverse of falling sheet at various part-gate and full-gate openings.	Ile Maligne Dam, Province of Quebec, Canada; R. F. Ewald.	Aluminum Co. of America.	Completed 1929; paper under preparation.	Discharge coefficients for large orifices vary with size of openings. Discharge capacity of a gate opening is affected by opening of adjacent gages.
Hydraulic model tests on large sluice tubes to carry diverted Saguenay River during construction of Chute-a-Caron dam.	Field laboratory of Alcoa Power Co., Ltd., at Ile Maligne, Quebec; R. F. Ewald.	Alcoa Power Co. Ltd. and Aluminum Co. of Am.	Proc. Engineers Society of Western Pennsylvania, Vol. 47, Jan. 1931; completed 1929.	A discharge of 50,000 sec.-ft. through a 40-ft. drop can be safely handled by sluice tubes without destructive action.
Investigation of various forms of stilling devices for water in open channels.	Pennsylvania State College; H. K. Kistler.	Pennsylvania State Col.	In progress.	
Analysis of water cushioning by dropping a precast dam into a river.	Carnegie Inst. of Tech.; A. J. Ackerman.	Aluminum Co. of America.	Completed 1930; paper under preparation.	A dam dropped into a river will be cushioned practically 100 per cent by the water.
Development of suitable rubber material with special characteristics for model dam testing.	Research Lab., Aluminum Co. of America, New Kensington, Pa., and Goodyear Tire & Rubber Co., Akron, Ohio; R. L. Templin, R. G. Sturm, A. V. Karpov, L. B. Sebrell.	Aluminum Co. of America and Goodyear Tire & Rubber Co.	Completed 1931; paper under preparation.	
Hydraulic jump.	State U. of Iowa.	State U. of Iowa.	In progress.	
Elimination of hydraulic eddy current loss at intake.	U. of Washington; Charles William Harris.	U. of Washington.	U. of Wash. Bulletin No. 54.	
Rainfall studies in North Carolina.	U. of North Carolina; Thorndike Saville.	U. of North Carolina and North Carolina Dept. of Conservation and Development.	In progress.	
Hyrological investigation in North Carolina.	U. of North Carolina; Thorndike Saville.	U. of North Carolina.	In progress.	Work includes evaporation from water surfaces, rate of silting in power and water supply reservoirs, diurnal fluctuation in flow of small streams, duration of flow curves and flood flows of North Carolina streams and drought studies.

WATER POWER

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Evaporation from reservoir surfaces.	Oklahoma Agr. & Mech. College; Edward R. Stapley, Rowland E. Kirkham.	Oklahoma Agr. & Mech. College.	In progress.	
Studies of meteorological data leading to methods of forecasting river flow.	Pennsylvania Water & Power Co.	Pennsylvania Water & Power Co.		
Study of the variation of stream flow and its effect on utilization.	U. of Wisconsin; D. W. Mead.	U. of Washington.	In progress.	
Cole pitometer test.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	E. S. Cole.		
Intake model experiments.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	H. S. Ferguson & Co.	Completed 1930.	
Tunnel experiments.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	H. L. Doherty & Co.	Completed 1930.	
Waterwheel and draft tube tests.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	I. P. Morris & De La Vergne, Inc.	Completed 1930.	
Tests on Laurentide draft tube.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	Shawinigan Engineering Co.	Completed 1930.	
Safe Harbor model test.	Alden Hydraulic Lab., Worcester Polytechnic Inst.; Prof. C. M. Allen.	Safe Harbor Water & Power Co.	Completed 1930.	
Investigation of mechanical vibrations in penstocks of hydraulic turbines.	Westinghouse Elec. & Mfg. Co. E. Pittsburgh; Dr. J. P. Den Hartog.	Westinghouse Elec. & Mfg. Co.	A.S.M.E. Trans., Vol. 51, 1929.	For the majority of conditions serious vibration in the penstock can be avoided by making the number of buckets different by two from the number of gates.
Study of large vertical waterwheel generator thrust bearing performance.	Westinghouse Elec. & Mfg. Co. E. Pittsburgh; C. R. Soderberg.	Westinghouse Elec. & Mfg. Co.		The limits of speed and pressure for this type of bearing were determined for practically any condition of speed and load. Accurate coefficients of friction for these conditions were determined.
Effect of viscosity of the water on the efficiency of a model francis turbine.	Hydraulisches Institut der Technischen Hochschule, Munchen, Germany; Dr. Ing. D. Thoma.	Notgemeinschaft der deutschen Wissenschaft.	Preliminary pub. Mitteilungen des Hydraulischen Instituts der Technischen Hochschule Munchen, Vol. 3, 1929, by F. Riemerschmid; in progress.	The efficiency of the turbine at lowest viscosity was about 3 per cent higher than at highest viscosity.
Transformation of kinetic energy to pressure energy in models of straight draft tubes.	Hydraulisches Institut der Technischen Hochschule, Munchen, Germany; Dr. Ing. D. Thoma.	Notgemeinschaft der deutschen Wissenschaft.	Report by A. Hofmann, in Mitteilungen des Hydraulischen Instituts der Technischen Hochschule Munchen, Vol. 4, 1931.	More than one thousand different arrangements were tested.
Energy conversion in nozzle-shaped suction pipes.	Hydraulic Inst., Munich Tech-U., Germany; A. Hofmann.	Munich Tech. U.	In progress.	
Influence of water tenacity on the efficiency of a small francis turbine.	Hydraulic Inst., Munich Tech. U., Germany; F. Riemerschmid.	Munich Tech. U.	In progress.	
Photo-elasticity test of turbine vane with polarized light.	Tech. Res. Inst. I.J.N., Japan; T. Tokugawa.	Imperial Japanese Navy.	In progress.	
Hydraulic efficiency of propeller turbine and pump.	Eng. College, Tohoku Imp. U., Japan; F. Numachi.	Tohoku Imp. U.	Eng. Col. of Tohoku Imp. U., Vol. 32, No. 152; completed.	
Study of guide vane of propeller turbine with pitometer tube.	Eng. College, Tohoku Imp. U., Japan; F. Numachi.	Tohoku Imp. U.	In progress.	
Water flow in and out of turbine pump impeller.	Yokohama College of Eng., Japan; M. Endo.	Yokohama Col. of Eng.	Scientific Report of Yokohama Technical College No. 1; completed.	

WELDING

Strength of welds in mild-steel plates at high temperatures.	Brown Boveri & Co., Baden, Switzerland.	Brown Boveri & Co.	Completed 1930.	Both electric and gas welds were tested.
Welding investigation as particularly related to Enduro tubes up to 10 in. dia. for 1,000 deg. F. steam.	Detroit Edison Co.	Detroit Edison Co.		
Metallographic study of metallic arc welds.	Case School of Applied Science; H. M. Boylston, A. Jenkin, J. C. Carpenter.	Amer. Bur. of Welding.	A.W.S. Jour. Sept., 1929; completed 1929.	
Stress-strain characteristics of welded joints.	U. of Pittsburgh; J. H. Smith.	Amer. Bur. of Welding.	A.W.S. Jour. Sept., 1929; completed 1929.	
Properties of welded joints.	Virginia Polytechnic Inst.; W. G. Conner.	Virginia Polytechnic Inst.	In progress.	
Study of welded metals under fatigue tests.	State College of Washington Eng. Exp. Sta.; S. E. Thornton, Douglas Blake.	A.B.W.	Bul. 34 of Washington Eng. Exp. Sta.; in progress.	Welded specimens of firebox steel do not equal endurance limit of that material unwelded.
X-ray analysis of welded joints.	Kaiser Wilhelm Inst. for Metal Research, Berlin-Dahlem; Dr. Ing. G. Sachs.	Kaiser Wilhelm Inst. for Metal Research.	In progress.	
Investigation of the nature of nitrogen needles.	General Electric Co.; P. P. Alexander.	Co-op. with American Bureau of Welding.	Progress report pub. in Sept., 1929, A.W.S. Jour.	It is believed needles are not due to nitrogen but to oxygen.
Study of influence of welding conditions and subsequent heat-treatment on the structure of welds.	American Chain Co., Bridgeport, Conn.; Karl Kuettner, V. N. Krevobok.	Amer. Bur. of Welding.	A.W.S. Jour., Dec., 1929.	
Investigation and testing of resistance of butt-welded light-gage tanks.	Lehigh U.	John Woods Mfg. Co., Amer. Bur. of Welding and A.S.M.E.	A.W.S. Jour., Feb., 1931; completed 1930.	Test on tanks with concave and convex heads were made.
Stress distribution in fillet welds.	U. of Pittsburgh.	Amer. Bur. of Welding.	A.W.S. Jour., Sept., 1929, and Sept., 1930; in prog.	
Study of locked-up stresses caused by welding heat.	Catholic U.	Amer. Bur. of Welding.		
Determination of proper welding procedure for welding with manufactured (city) gas.	Purdue U.	Co-op. with Utility Research Comm.	In progress.	

WELDING

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation and development of new methods of testing welding.	U. of Michigan; Prof. W. O. Freyberg.	Detroit Edison Co.	In progress.	The normal magnetic-flux component method for the testing of welds has been developed. Apparatus for the testing of welds in the shops and field are being developed and tested out.
Chemical reaction of the carbon arc.	U. of Lehigh; G. E. Doan, E. Ekholm.	Amer. Bur. of Welding and U. of Lehigh.	A.W.S. Jour., Sept., 1929.	With arc lengths greater than ¼ in. and welding currents up to 300 amp. no carbon is absorbed by the weld.
Cathode energy of the iron arc.	Amer. Bur. of Welding Fundamental Research Committee; G. E. Doan.	Amer. Bur. of Welding.	A.W.S. Jour., March, 1930.	
Welds at elevated temperatures.	U. of Stanford.	Amer. Bur. of Welding.	A.W.S. Jour., Sept., 1928.	
Investigation of internal stress produced by fillet welds made by metalic arc.	Rensselaer Polytechnic Inst.	Amer. Bur. of Welding.	In progress.	
Study of use of gamma ray for examining welds.	Naval Research Laboratory; R. F. Mehl, G. Doan, C. S. Barrett.	Naval Research Lab.	A.W.S. Jour., Sept., 1930; in progress.	
Examination of welds by the X-ray diffraction method.	Massachusetts Inst. of Tech.; John T. Norton.	American Welding Bur.	A.W.S. Jour., Sept., 1930; in progress.	
Non-destructive testing of welds by means of the stethoscope and X-ray.	Union Carbide & Carbon Research Lab.; A. B. Kingel, C. O. Burgess, A. R. Lytle.	Union Carbide & Carbon Corp.	A.W.S. Jour., Sept., 1929.	Defects in line welds, girth seams or joints may be detected by stethoscope and a quantitative estimate by X-ray.
X-ray examination of welds.	Watertown Arsenal; Major J. B. Rose.	Watertown Arsenal.	A.W.S. Jour., Sept., 1929.	
Non-destructive test of welds by electric-resistance method.	Sperry Development Co.; E. A. Sperry.	Sperry Development Co.	A.W.S. Jour., Sept., 1929.	
Weld testing by measurement of magnetic potentials.	Westinghouse Electric & Mfg. Co.; T. R. Evatts.	Westinghouse Elec. & Mfg. Co.	A.W.S. Jour., Sept., 1930; in progress.	Weld testing by this method is more quantitative and more nearly free from personal judgment than the magnetographic method.
Magnetic testing of butt welds.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; T. R. Watts.	Westinghouse Elec. & Mfg. Co.	A.W.S. Jour., Sept., 1930; in progress.	Magnetographic inspection a valuable means of discovering serious faults, particularly poor fusion.
Preliminary investigation of method of testing fillet welds.	U. of Toronto; Prof. P. Gillespie.	Amer. Bur. of Welding.	A.W.S. Jour., March, 1929; in progress.	
Investigation of methods of testing welds.	Babcock & Wilcox Co.	Babcock & Wilcox Co.	*Power*, Oct. 7, 1930.	
Fatigue tests of fillet welds to determine effect of machining spacing and size of weld.	Westinghouse Elec. & Mfg. Co., East Pittsburgh; R. E. Peterson, C. H. Jennings.	Westinghouse Elec. & Mfg. Co.	A.S.T.M. Proceedings, Vol. 30, Part II; in progress.	
Fatigue and impact tests of welds.	Westinghouse Elec. & Mfg. Co., Pittsburgh; C. H. Jennings.	Westinghouse Elec. & Mfg. Co.	A.W.S. Jour., Sept., 1930.	Need of tentative standard for dynamic tests of welds is indicated.
Corrosion fatigue tests of welded joints.	Lehigh U.; W. E. Harvey.	Lehigh U.	In progress.	
Development of methods of oxy-acetylene welding of corrosion-resisting metals and alloys.	Union Carbide & Carbon Research Lab.; W. B. Miller.	Union Carbide & Carbon Corp.	A.W.S. Jour., July and Dec., 1930.	
A system for direct-current arc welding.	General Electric Co., S. R. Bergman.	General Electric Co.	A.I.E.E. Midwinter Convention, 1930.	
Influence of magnetism on the welding arc.	General Electric Co., R. M. Stephens.	General Electric Co.		
Classification and physical tests for various types of welded-plate joints.	General Electric Co.; G. R. Exley.	General Electric Co.	G. E. Review, 1930, pp. 581-591.	
The welding of ferrous and non-ferrous metals by the atomic-hydrogen flame.	General Electric Co.; H. G. Reist.	General Electric Co.	G. E. Review, 1929, pp. 597-601.	
Tests of metal arc welds.	General Electric Co.; Andrew Vogel.	General Electric Co.	G. E. Review, 1929, pp. 332-340.	

MISCELLANEOUS

A study of chimney performance.	Johns Hopkins U.; A. G. Christie, J. C. Smallwood.	Johns Hopkins.	Projected probable date completed, June, 1932.	
Investigation of temperature drop, gas velocities, draft variation, gas composition and friction loss in brick stack.	Cornell U.	Cornell U.	In progress.	
Prediction of centrifugal fan characteristics from tests on stationary apparatus.	Lafayette College; E. M. Fernald.	Lafayette College.	In progress.	
Investigation of the causes of blower noise.	N. Y. Edison system.	N. Y. Edison system.	Completed.	
Stresses in draft fans due to starting and speed changing.	N. Y. Edison system.	N. Y. Edison system.	Completed.	Stress conditions are reduced by using motors having low starting and pull-out torque.
Study of performance and testing of disk and propeller fans. Most of work has been on airplane propeller-type fans, and includes effect of design of the fan ring and discharge.	Ohio State U. Mech. Eng. Lab.; A. I. Brown.	Ohio State U.	Progress report presented to A.S.H.V.E., Jan., 1930.	Propeller fans are found to be highly efficient within the range of pressure for which they are designed, and have characteristics closely resembling centrifugal fans.
Balanced-damper design by shifting axis of damper away from central position.	N. Y. Edison system.	N. Y. Edison system.	In progress.	
Study of damper design, including investigation of effect of number of leaves, effect of streamlining.	Buffalo Forge Co.; A. A. Criqui.	Buffalo Forge Co.		
Tests on elevator buffers.	U. S. Bureau of Standards; J. A. Dickinson.	A.S.M.E.	Completed 1930.	
Tests on elevator under-car safeties.	U. S. Bureau of Standards; J. A. Dickinson.	A.S.M.E.	In progress.	
Research on wire ropes.	Woolwich Polytechnic, England; Dr. W. A. Scoble.	Woolwich Polytechnic, England.	Completed 1930.	Comparison of ropes over chilled and ordinary C.I. pulleys.
Development of test procedure for determining electrical conductivity of steam and condensate.	Detroit Edison Co.	Detroit Edison Co.	Completed 1931	
Mechanical refrigeration	U. of Illinois.	U. of Illinois, Mech. Eng. Dept. and Eng. Exp. Sta.	Three bulletins of the Eng. Exp. Sta., Nos. 171, 186, 209, in progress.	
Tests to compare actual capacity of multiple-effect ammonia compressors with the theoretically calculated capacity.	Vilter Mfg. Co. Research Lab.	Vilter Mfg. Co.	In progress.	

MISCELLANEOUS

Project	Location of Research—Directed by	Sponsor	Status and Published Results	Remarks
Investigation of necessity of expansion joint in underground steam piping.	Philadelphia Elec. Co.	Philadelphia Elec. Co.	In progress.	
Strength under reverse load of 12-, 16- and 20-in. C.I. pipe with different type of joints.	Civil Eng. Lab., Towne Scientific School, U. of Pennsylvania, and at Case School of Ap. Science.	American Gas Assn.	In progress.	
Operation of centrifugal pumps under abnormal conditions.	Hydraulisches Inst. der Tech. Hochschule, München, Germany; Dr. Ing. D. Thoma.	Hydraulisches Inst. der Tech. Hochschule.	Mitteilungen des Hydraulischen Inst. der Tech. Hochschule München. Vol. 4, 1931; in progress.	
Study of noise-measuring apparatus.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; C. R. Hanna, J. P. Foltz.	Westinghouse Elec. & Mfg. Co.	Trans. A.I.E.E., Vol. 48, 1929.	The research laboratory model consists of a microphone for picking up the sound, a vacuum tube amplifier, an electrical filter circuit combination, and meter.
To determine the effect of flexibility of rotor spiders of diesel and gas engine driven generators on torsional vibration critical speeds.	Westinghouse Elec. & Mfg. Co., E. Pittsburgh; C. R. Soderberg.	Westinghouse Elec. & Mfg. Co.		As a result of studies on several types and sizes of rotor spiders, it is now possible to predetermine accurately the effect of spider construction on the torsional critical speeds.
Load—deflection relation of corrugated and creased pipe bends.	Detroit Edison Co.	Detroit Edison Co.	Completed 1931	
Electrical method for determining the dew-point of flue gas.	U. of Illinois; H. F. Johnstone.	U. of Illinois.	Circular No. 20 U. of Illinois Eng. Exp. Sta., 1929.	Dew-point of furnace gas can be measured by an electrical device based on the conductivity of glass surface with accuracy of 2 deg. C for low concentrations of SO_3 and 10 deg. C. for high concentrations. Estimate of dew-point may be made if SO_3 concentration is known together with usual Orsat gas data.
Spectographic analysis of gas.	Detroit Edison Co. and U. of Mich.	Detroit Edison Co.		
Specific heat of gases at high pressures.	U. of Illinois.	U. of Illinois and Eng. Exp. Sta.	Jour. of Amer. Chem. Soc., Jan., 1930, Dec., 1930, and Oct., 1930; work completed.	
Study of power generation from the ocean utilizing difference in temperature between surface water and that at considerable depth.	Cuba; Georges Claude.			
Power transmission with cast-iron pulleys and with paper pulleys and the transmissive power of tanned leather and rubber belts with varying contact angles.	Ohio State U.; Prof. C. A. Norman, Asst. Prof. G. M. Moffat.	Ohio State U. Mech. Eng. Dept. and Rockwood Mfg. Co.	In progress.	
Efficiency of power screws and collar thrust bearings.	U. of Illinois.	U. of Illinois Mech. Eng. Dept. and Eng. Exp. Sta.	In progress.	To determine the coefficients of friction of power screws, operating under various conditions of load, speed and lubrication.
Development of a dynamometer for determining power transmitted by shafts in regular service without necessity of absorbing the power.	Pennsylvania State College; M. S. Giesdahl.	Pennsylvania State Col.	In progress.	A design has been completed and is being built.
Strength of vessels under external pressure.	Model base, Navy Yard, Wash.; Commander Saunders.	Model base, Navy Yard, Wash., A.S.M.E. co-op.	In progress.	
Effect of differences in pressure on operation of Holly drip system.	Hudson Ave.	N. Y. Edison system.	Completed 1930.	
Study of 24-in. rubber guide bearing and non-corrosive metal for shaft bushing.	Pennsylvania Water Power Co.	Pennsylvania Water Power Co.		
First cost of power plants as affected by pressure.	U. of Alabama; J. M. Gallalee.	U. of Alabama.	In progress.	
Measurement of noises of certain reduction gears used in central stations.	U. of Michigan and Detroit Edison Co.'s plant; E. J. Abbott.	Detroit Edison Co.	In progress.	It appears that the method employed in this investigation has value in specifying the loudness and quality of these gear noises in absolute units and in determining the particular parts of the machine responsible for the noise and something of the nature of the defects.
Fire suppression in generators.	K. Janak.	K. Janak.	E.u.M., 48, p. 817, Sept. 7, 1930.	Tests on 9,000-kva. turbine-alternator show CO_2 more effective than nitrogen for rapid extinguishing of fire in windings.
Bending of curved pipes.	Massachusetts Inst. of Tech.; William Hovgaard.	Mass. Inst. of Tech.	Jour. of Math. and Physics, 1926-1929; completed.	Nine full-scale pipe bends were tested.
Investigation of the effect of temperature on the physical properties of ice.	Rensselaer Polytechnic Inst.	Rensselaer Polytechnic Inst.	In progress.	
Temperature stresses in constant-pressure heat accumulators.	Central station at Mannheim; Edward Mayer, Karlsruhe.	Central station at Mannheim.	Completed 1930.	Maximum stresses occur when accumulators are one-half filled with water and are neither receiving nor giving off heat.
Relation between the treatment of boiler materials and corrosion cracks.	Locomotive Mfg. Co., Japan; S. Iguchi.	Locomotive Mfg. Co.	In progress.	
Experimental development of the Thoma return-flow brake.	Hydraulic Inst., Munich Tech. U., Germany; R. Heim.	Hydraulic Inst. Munich Tech. U.	Completed.	Test observations determined proper contour of tangential nozzle to minimize cavitation effect. A practical non-return valve without moving parts can be developed.
Noise elimination of high-speed blower.	Res. Inst. Mitsubishi Ship Bldg. & Eng. Co., Japan; K. Suyehiro.	Res. Inst. Mitsubishi Ship Bldg. & Eng. Co.	In progress.	
Shaft behavior at critical speed.	General Electric Co.; H. D. Taylor.	General Electric Co.	G. E. Review, 1929, pp. 194-200.	
Study whirling balanced shafts.	General Electric Co.; B. L. Newkirk.	General Electric Co.	To be published.	
Elastic supports for isolating rotating machinery.	General Electric Co.; E. H. Hull, W. C. Stewart.	General Electric Co.	To be published.	Part of general study of noise in electric machinery.
The measurement of machinery noise.	General Electric Co.; H. B. Marvin.	General Electric Co.	To be published.	Part of general study of noise in electric machinery.
Influence of damping in the elastic mounting of vibrating machines.	General Electric Co.; E. H. Hull.	General Electric Co.	To be published.	
Electrohydraulic devices for producing straight-line motion.	General Electric Co.	General Electric Co.	Completed.	Research prior to the development of the G. E. "Thrustor."

NEWS of the FIELD

National Electric Light Association Convention in Atlantic City, June 8-12

THE 54TH CONVENTION of the National Electric Light Association will be opened at 10 a.m. Tuesday, June 9, in the ballroom of the Atlantic City Auditorium, Atlantic City, N. J., with W. Alton Jones, president, presiding. It will be preceded Monday, June 8, by committee meetings and a president's reception. There will be four general sessions on the mornings of the 9th, 10th, 11th and 12th, the afternoons being devoted to sessions of the engineering, accounting, commercial and public relations national sections.

On Tuesday morning the association will be welcomed to Atlantic City by Mayor Harry Bacharach, who will be followed by W. Alton Jones, president, and Paul S. Clapp, managing director. Other speakers at this session are: M. H. Aylesworth, president of the National Broadcasting Company; Harry Reid, president of the National Electric Power Company; David Lawrence, editor and publisher of the *United States Daily;* Robert F. Pack, former president of the N.E.L.A.

The program of the second general session, Wednesday morning, will include E. W. Goldschmidt, chairman of the exhibition committee; Judge William Lynn Ranson; J. F. Owens, president of the Oklahoma Gas & Electric Company, who will discuss trade relations; T. O. Kennedy, vice-president and general manager of the Ohio Public Service Company; and Gus W. Dyer, editor of the *Southern Agriculturist.*

W. Alton Jones

On Thursday morning the third general session will open with a report on memorials by W. H. Onken, Jr., vice-president of the Security Owners Association. C. E. Groesbeck, president of the Electric Bond & Share Company, will discuss the possible connection, if any between the world-wide business depression and the invasion of governments in the various fields of private enterprise not only in this country but in other countries. He will be followed by W. C. Mullendore, vice-president of the Southern California Edison Company, whose speech on "The Power Industry and Political Sabotage," delivered before the Pacific Coast Electrical Association last February, is still being talked about.

The session will close with an address by Samuel Insull who began his career in the light and power industry as private secretary to Thomas A. Edison in 1881 and who, after 50 years of continuous service, is still one of the most active and prominent leaders in the public utility field.

The program of the fourth general session, which will close the convention, will include such men as Gerard Swope, president of the General Electric Company; Marshall E. Sampsell, president of the Society for Electrical Development; Edwin Gruhl, vice-president and general manager of The North American Company; Franklyn Heydecke, Public Service Electric & Gas Company; and Frank W. Smith, vice-president and general manager of the United Electric Light & Power Company. Mr. Smith will announce the winners of the various prize awards administered by the National Electric Light Association and the various donors, who will be present, will make the presentations.

The public policy session, will be held on the evening of Thursday, June 11, in the ballroom of the auditorium. After announcing the winner of the Charles A. Coffin medal and prize award, Preston S. Arkwright, chairman of the public policy committee, will make his report. He will be followed by Merle Thorpe, editor of *Nation's Business,* who will speak on the subject of "Our Vanishing Economic Freedom."

The accounting national section will hold its annual meeting on Tuesday afternoon, June 9, in Westminster Hall,

Atlantic City Auditorium where the convention sessions and exhibition will be held

Hotel Chelsea. General accounting subjects will be discussed, including the coordination of accounting with public relations. An interesting item on the program will be the presentation of his nationally famous lecture "How to Fail," by Fred D. Van Amburgh. The engineering national section will hold its annual meeting on the same afternoon in the ballroom of the auditorium. The program will include "Economic Wastes," by George N. Tidd, president of the American Gas & Electric Company; "Smoke Problems," by Harvey N. Davis, president of the Stevens Institute of Technology; and "Distribution Costs," by A. C. Marshall, vice-president of the Detroit Edison Company. The commercial national section will meet in the ballroom on Wednesday afternoon, June 10.

The meeting of the Public Relations National Section, in the ballroom on Thursday afternoon, June 11, will be presided over by Chairman Reid. Chairman Joseph B. Groce will discuss the work of the advertising and publicity committee. He will be followed by James B. Black of the North American Company, who will speak on "Customer Ownership." Homer Ferguson, past president of the United States Chamber of Commerce, will discuss "Government in Business" and Homer E. Niesz will talk on employee training.

A.S.H.V.E. Reorganizes Research Activities

ANNOUNCEMENT is made by the American Society of Heating and Ventilating Engineers of the adoption of a new and comprehensive policy in regard to cooperative research activities, which has been developed as the result of ten years' experience in this field.

Under the new plan, centralized control is maintained through the chairman of the committee on research with the assistance of a technical advisor. Chairman C. V. Haynes announces that Arthur C. Willard, professor of heating and ventilation and head of the mechanical engineering department at the University of Illinois, has been appointed to the newly created position of technical advisor.

All matters of policy will be determined by the committee on research as a whole and all business affairs remain in the hands of the chairman and the executive committee. A technical advisory committee will be assigned to each research problem and will report to the chairman of the committee on research.

A renewal of the contract with the United States Bureau of Mines has been approved, it is stated, and the investigations in Pittsburgh will be directly in charge of F. C. Houghten, director of the society's research laboratory. The latest cooperative agreement has been made with the University of Illinois and the problems assigned to that institution are under the immediate supervision of Prof. A. P. Kratz.

Thirty-Three-Year Old Boiler Explodes At Canton, Miss., Electric Plant

AT 8 P.M. on April 5 a 1,500-sq.ft. Stirling boiler in the plant of the Canton Electric Light & Water Works, Canton, Miss., exploded, killing three men, injuring three others and damaging plant building and machinery to the extent of about $35,000.

From W. M. Reid, superintendent of the company, it was learned that the boiler had been installed in 1898, and had been used steadily for the first six years thereafter, but for the remaining twenty-seven years had been retained as reserve equipment, being used two days in each month while the other boiler was being washed out.

At the time of the last insurance inspection, Oct. 27, 1930, no serious scale was noted and no evidence of corrosion was detected in any of the drums or tubes. A hydrostatic test of 225 lb. gage, applied in May, 1930, revealed no sign of leakage. At the time of this test, a $\frac{13}{32}$-in. hole was drilled in the lower side of the shell of the mud drum, at a point where external corrosion appeared to be worse than elsewhere. The metal at this point measured $\frac{3}{8}$-in. thick, and the hole was tapped and plugged.

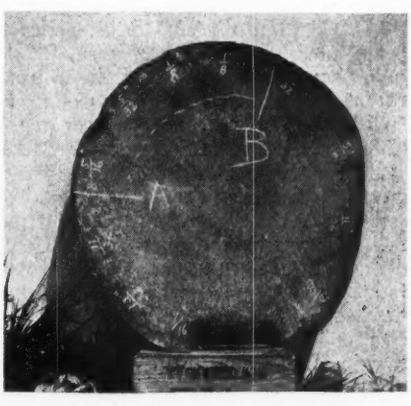
A recording pressure gage, located in the engine room, was unharmed. This instrument gave the exact time of the explosion and showed that the pressure at the time was 150 lb., the pressure approved for this boiler.

Examination of the wreckage revealed the mud drum as the seat of the trouble. The rear end of this drum had opened up much like a huge tomato can. The line of rupture followed the heel of the flange throughout its entire course. The thickness of metal varied from $\frac{3}{8}$ in. at the top to $\frac{5}{32}$ in. at the bottom, presumably the point where rupture started.

Representatives of the boiler company and of the insurance company, as well as the plant management, agree that external corrosion was the cause of the explosion. The rear end of the mud drum being bricked up without access doors prevented proper inspection, and the fact that the boiler was idle most of the time permitted moisture and soot to collect about the head and waste away the metal until there was not sufficient to withstand the pressure carried.

The boiler room was demolished leaving the second boiler standing

One illustration shows the remaining boiler practically unharmed, although the four walls of the boiler room were razed. The mud drum, with tubes and rear steam drum, was hurled into the engine room, taking the valve mechanism off a uniflow engine. The middle steam drum struck a 15-in. I-beam supporting the roof, and fell in the boiler room. The front steam drum landed 185 yd. away in a pasture.



Head and part of drum with thickness of flange indicated

Supreme Court Dismisses Arizona's Hoover Dam Suit

THE SUPREME COURT of the United States on May 18 dismissed the suit brought by the State of Arizona against the Secretary of the Interior and the States of California, Nevada, New Mexico, Utah, Colorado and Wyoming to prevent construction of Hoover Dam under the Boulder Canyon Project Act.

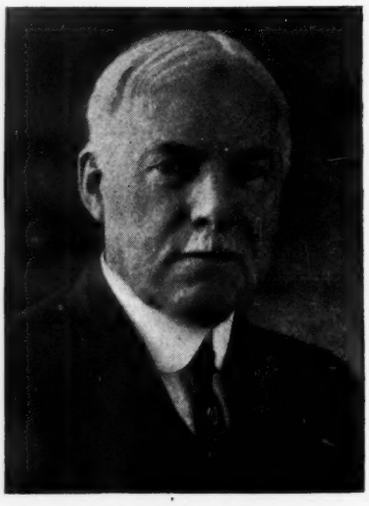
In his opinion dismissing the suit, Justice Brandeis answers the contention of Arizona that its quasi-sovereign rights to appropriate water will be interfered with by declaring that no present infringement exists and for that reason the suit should be dismissed without prejudice to the state to bring suit in the future when its rights should be violated. The fact that Arizona did not enter into the compact of western states relative to the division of waters of the Colorado River leaves its legal rights unimpaired, according to the decision.

Arizona's bill of complaint was filed in the Supreme Court on Oct. 13, 1930.

Dr. Parr, Fuel Chemist, Dies of Heart Failure

DR. SAMUEL WILSON PARR, professor emeritus of applied chemistry at the University of Illinois, died on May 16 at his home in Urbana, Ill., as the result of a heart attack.

Dr. Parr was widely known for his experimental investigations in the calorimetry of fuels and the development of the Parr low-temperature process for coking Illinois coal. He invented an automatic gas calorimeter and his experiments with the bomb calorimeter



Samuel W. Parr

led him to the discovery of "Illium," an inexpensive alloy having acid-resisting properties that make it suitable for use as a platinum substitute.

Born in Granville, Ill., on Jan. 21, 1857, Professor Parr graduated from the University of Illinois in 1884. He spent a year in graduate work at Cornell University, for which he received the degree of master of science. He also studied at the universities of Berlin and Zurich in Germany. In 1891 he was made professor of applied chemistry at the University of Illinois, and following the death of Prof. A. W. Palmer in 1904, he became head of the department.

Besides his activities at the university, Dr. Parr acted as consulting chemist for the Illinois state water survey, the engineering experiment station, and the coal investigation department of the state geological survey. He had charge of practically all research on the chemical and physical properties of Illinois coal and was instrumental in developing standard values for coal.

One of his more recent investigations led to the development of the Parr treatment for boiler feed water to prevent rapid embrittlement of the boiler metal.

He was a member of the American Chemical Society, Institute of Chemical Engineers, American Institute of Metals, International Railway Fuel Association, American Society for Testing Materials, American Institute of Mining and Metallurgical Engineers, Illinois Water Works Association and a fellow of the American Association for the Advancement of Science.

COMING CONVENTIONS

American Society of Mechanical Engineers. Meeting at Hartford, Conn., June 1-3. National Oil and Gas Power Meeting at the University of Wisconsin, Madison, Wis., June 23-26. Secretary, Calvin Rice, 33 West 39th St., New York City.

American Institute of Electrical Engineer. Annual summer convention in Asheville, N. C., June 22-26. District meeting at Lake Tahoe, Calif., Aug. 25-28. Secretary, F. L. Hutchinson, 33 West 39th St., New York.

American Society of Heating and Ventilating Engineers. Semi-annual meeting at the New Ocean House, Swampscott, Mass., June 22-26. Secretary, A. V. Hutchinson, 51 Madison Ave., New York City.

American Society for Testing Materials. Annual meeting at the Stevens Hotel, Chicago, Ill., June 22-26. Secretary, C. L. Warwick, 1315 Spruce St., Philadelphia, Pa.

Association of Iron and Steel Electrical Engineers. Annual meeting and exposition at the Cleveland Public Auditorium, Cleveland, Ohio, June 15-19. Managing director, John F. Kelly, Empire Building, Pittsburgh, Pa.

National Association of Power Engineers. Annual convention and mechanical exposition in the Convention Hall, Kansas City, Mo., Sept. 7-11. Secretary, Fred W. Raven, 417 South Dearborn St., Chicago.

Third International Conference on Bituminous Coal. At Carnegie Institute of Technology, Pittsburgh, Pa., Nov. 16-21. Chairman, Thomas S. Baker, president of Carnegie Institute of Technology.

Universal Craftsmen Council of Engineers. Annual convention at the Sherman Hotel, Chicago, Ill., Aug. 4-8. Secretary of Convention Committee, James J. Blaine, 7342 Harvard Ave., Chicago, Ill.

Axel L. Hadin Dies

AXEL L. HADIN, chief engineer of Calumet station of the Commonwealth Edison Company, Chicago, died on May 19, after a lingering illness dating from Nov. 5, 1930. Born at Ostergotland, Sweden, on Dec. 26, 1859, Mr. Hadin came to this country in 1880, going to Clay Center, Kan., where he obtained a position as chief engineer of the Manhattan Water Works. Eleven years later he moved to Aurora, Ill., to take charge of the plant of the Aurora Street Car & Electric Power Company. In 1897 he became chief engineer of the Chicago Elevated Railway power plants.

In the course of time these plants were discontinued and the electrical services to the foregoing transportation facilities were taken over by the Commonwealth Edison Company. Twenty-four years' service with the elevated lines established Mr. Hadin as an executive engineer of such marked ability that in 1921 he was made chief engineer of Calumet station, then building. He was a member of the National Association of Power Engineers.

Personals

ALBION DAVIS, formerly chief engineer of the Mississippi River Power Company, has been appointed chief hydraulic engineer of the Union Electric Light & Power Company. Other changes in the St. Louis company's personnel include the following: STANLEY STOKES, assistant vice-president, has been made consulting electrical engineer; GEORGE K. MILTENBERGER, assistant vice-president, is now general superintendent of the company; and J. TURNER WHITE, JR., has been placed in charge of the operation of the new hydro-electric plant on the Osage River.

MALCOLM C. CLEVELAND, of New York City, has been appointed chief engineer of the New York Public Service Commission to succeed CHARLES R. VANNEMAN, who resigned to establish his own engineering firm. Mr. Cleveland has been engaged in engineering work for the past 30 years.

PROF. DUGALD C. JACKSON, head of the electrical engineering department at the Massachusetts Institute of Technology, was recently reelected chairman of the National Research Council's Division of Engineering and Industrial Research. The two vice-chairmen, also reelected, are DR. D. S. JACOBUS, advisory engineer of the Babcock & Wilcox Company, and DR. BYRON E. ELDRED, engineer of New York City.

R. H. BALLARD, president of the Southern California Edison Company, was elected to the board of directors of the California Chamber of Commerce. Mr. Ballard has been active in committee work for the state chamber of commerce for the past several years.

R. B. PACK, vice-president and general manager of the Northern States Power Company since 1916, has been elected president of the company to succeed JOHN J. O'BRIEN, who, as president of Byllesby Engineering & Management Corporation and Standard Gas & Electric Company, has also been president of the affiliated companies.

JOHN HARISBERGER has been made manager of the newly created division of power supply of the Puget Sound Power & Light Company. M. T. CRAWFORD, formerly superintendent of distribution for the company, is now general manager of the light and power department; J. HELLENTHAL is electrical engineer; B. R. SHUTT is superintendent of distribution; W. C. WHIPPLE is superintendent of substations; and A. W. MATHIS is superintendent of system operation.

RALPH W. E. MOORE, formerly manager of association activities of the Westinghouse Electric & Manufacturing Company, has been placed in charge of the magazine of the National Electric Manufacturers Association, which will resume issue in June.

Business Notes

READING IRON COMPANY, Reading, Pa., announces the following changes in its sales organization: J. K. Aimer has been appointed assistant general sales manager; W. S. Shiffer has been made assistant to the general sales manager; R. I. Fretz has been transferred from the Reading district to assume charge of the Pittsburgh district in place of Wyman Howells, who will now direct the activities of the Reading district; Harry L. Bialock is now associated with the St. Louis district; L. C. Hartzell is working under the direction of R. W. Thompson at Reading; George D. Smith has been made railroad salesman under the direction of Mr. Aimer in New York; and R. S. Moorehead has been appointed to the Pittsburgh district.

LINK-BELT COMPANY, Chicago, Ill., announces that William L. Hartley, formerly in charge of the foundry sales division, is now district sales manager in charge of the Detroit territory, with headquarters at 5938 Linsdale Ave., Detroit, Mich.

GRINDLE FUEL EQUIPMENT COMPANY, Harvey, Ill., a subsidiary of the Whiting Corporation, has purchased the exclusive manufacturing and selling rights to the Bethlehem pulverizer formerly manufactured by the BETHLEHEM STEEL COMPANY.

YEOMANS BROTHERS COMPANY, Chicago, Ill., announces the appointment of the following new representatives: Andriot Davidson Company, 1307 Starks Bldg., 4th & Walnut St., Louisville, Ky.; Johns Equipment Company, First National Bank Bldg., Fort Wayne, Ind.; and H. A. Grossman Company, 3221 Olive St., St. Louis, Mo.

TRUSCON STEEL COMPANY, Youngstown, Ohio, announces the appointment of Garret A. Connors as vice-president and director of purchases. Mr. Connors has been an executive in the production division of the company for the past 24 years.

C. J. TAGLIABUE MANUFACTURING COMPANY, Brooklyn, N. Y., announces the opening of a branch sales office at 2832 East Grand Blvd., Detroit, Mich. H. W. Kerr, who has had many years experience in solving temperature problems, has been placed in charge of the new branch.

THE KORFUND COMPANY, Long Island City, N. Y., has recently moved into a new plant located at 48-15 Thirty-Second Pl., Long Island City. Much additional manufacturing and office space is available in the new factory, it is stated, and plans are being made to add new machinery and enlarge the engineering department and experimental laboratory. The company reports a "most successful year for 1930 with a steady volume in the first quarter of 1931."

How's Business?

UNRELIEVED MONOTONY of general trade stagnation shown in the weekly indicators tends to obscure underlying currents of encouragement and tempts the imaginative to dramatize the tedium with rumors of further difficulties impending. Our index, still oscillating around the depression level, neither fully reflects these undercurrents nor justifies these fears. The relative strength of residential building is one of certain indicators that suggest slow improvement in fundamental factors. Most important of all is the plain indication that Federal Reserve credit policy is pointed toward expansion and that its persistent pressure is beginning to break down resistance in the interest rate structure and to bring reassuring results in the bond market, at least for the large governmental issues, to support the public construction that may ultimately be necessary to stimulate recovery or meet unemployment emergencies. —*The Business Week*, May 27.

Trade Catalogs

SPEED REDUCERS—Catalog No. 301 on worm-gear speed reducers has just been issued by the Foote Bros. Gear & Machine Company, 215 North Curtis St., Chicago, Ill. This publication covers fully the changes and improvements in worm-gear design since its earliest form and presents original information in regard to manufacturing methods, materials and selection of units, and efficiencies heretofore unavailable.

CONVEYORS—Catalog No. 495, just issued by the Jeffrey Manufacturing Company, contains full descriptions of spiral conveyors suitable for handling coal, cement, soda ash, grain, lime, powdered clay, asphalt, molasses and similar materials of a loose or bulky nature.

CONSTRUCTION—"Cutting Construction Costs" is the title of a comprehensive report on the cost of accidents in the construction industry, which has just been issued by the special risk and engineering department of the Hartford Accident & Indemnity Company, Hartford, Conn.

GASOLINE ENGINES—A new bulletin of the Sterling Engine Company, Buffalo, N. Y., describes and illustrates the construction features of the company's high-duty gasoline engines for stationary work.

METALS—Information on the use of nickel and Monel Metal in heavy equipment is contained in a recent publication of the International Nickel Company, 67 Wall St., New York City, entitled "Engineering Metals for the Process Industries." Another new bulletin, No. 208, of the company covers the characteristics and applications of "Ni-Resist," a corrosion- and heat-resistant nickel-copper-chromium cast iron.

MECHANICAL DRIVES—A new catalog, No. 1293, entitled "A Saving at Every Turn," has just been issued by the Link-Belt Company, 910 South Michigan Ave., Chicago, Ill. It describes and illustrates the company's complete line of positive drives including silent chain, roller chain, herringbone gears, herringbone speed reducers, worm-gear speed reducers, steel and malleable chains.

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Fuel Prices

FUEL OIL

Boston—May 18, tank-car lots, f.o.b. 12@14 deg. Baumé, 2.9c. per gal.; 28@32 deg., 4.85c. per gal.

New York—May 21, f.o.b. Bayonne, N. J., 28@34 deg. Baumé, industrial use, tank-car lots, 4.5c. per gal.; f.o.b. Bayway, 36@40 deg., furnace, tank-car lots, 6c. per gal.

Philadelphia—May 20, No. 3, industrial gas oil, $1.83 per bbl.; No. 4, light industrial fuel oil, $1.31 per bbl.; No. 5, medium industrial fuel oil, $1.20 per bbl.; No. 6, heavy (Bunker C), $1.05 per bbl.

Pittsburgh—May 12, f.o.b. local refinery, fuel oil, 30@34 deg., 2.75c.@2.875c. per gal.; 36@40 deg., 2.75c.@2.875c. per gal.

Cincinnati—May 12, tank-car lots, f.o.b. local refinery, 24@26 deg. Baumé, 4.5c. per gal.; 26@30 deg., 4.75c. per gal.; 30@32 deg., 5c. per gal.

Chicago—May 18, tank-car lots, f.o.b. Oklahoma; freight to Chicago, 90c. per bbl. or 42 gal.; 18@22 deg., 37.5c. per bbl.; 22@24 deg., 42.5c. per bbl.; 24@26 deg., 45c. per bbl.; 26@28 deg., 55c. per bbl.; 28@30 deg., 65c. per bbl.

St. Louis—May 19, tank-car lots, f.o.b. St. Louis, 24@26 deg., $1.17 per bbl., or 42 gal.; 26@28 deg., $1.27 per bbl.; 28@30 deg., $1.37 per bbl.; 30@32 deg., $1.47 per bbl.; 32@36 deg., gas oil, 2.776c. per gal.; 38@40 deg., distillate, 3.526c. per gal.

Dallas—May 16, f.o.b. local refinery 24@26 deg., $1.05 per bbl. or 42 gallons.

COAL

Bituminous (Net Tons)	At Mine, for Shipment to	Price per Ton
Pool 9, super low-vol.	New York	$1.70 @ $1.90
Pool 10, h. gr. low-vol.	New York	1.60 @ 1.70
Pool 11, low-vol.	New York	1.40 @ 1.50
Smokeless, mine-run	Chicago	1.50 @ 1.75
Smokeless, slack	Chicago	1.00 @ 1.25
Harlan, Ky., slack	Chicago	1.10 @ 1.20
Franklin, Ill., mine-run	Chicago	2.15
Franklin, Ill., screen	Chicago	1.50 @ 1.75
Ind. 5th Vein, m.-r.	Chicago	1.20 @ 1.75
Standard Ill., mine-run	St. Louis	1.25 @ 1.40
W. Ky., mine-run	Louisville	.85 @ 1.25
W. Ky., slack	Louisville	.70 @ .80
Pittsburgh, mine-run	Pittsburgh	1.35 @ 1.45
Smokeless, mine-run	Cincinnati	1.65 @ 1.75
Smokeless, slack	Cincinnati	1.00 @ 1.25
Kanawha, mine-run	Cincinnati	1.10 @ 1.35
Kanawha, nut-slack	Cincinnati	.75 @ 1.15
Anthracite (Net Tons)	At Mine, for Shipment to	Price per Ton
Buckwheat	New York	$3.25 @ $4.00
Barley	New York	1.00 @ 1.40

New Plant Construction

COMPILED BY THE McGRAW-HILL BUSINESS NEWS DEPARTMENT, WHICH IS PREPARED TO FURNISH A MORE COMPLETE DAILY SERVICE TO THOSE WHO WISH IT

Calif., Brawley—City plans an election soon to vote $150,000 bonds for the construction of a power plant. Burns-McDonnell-Smith Engineering Co., Western Pacific Bldg., Los Angeles, is engineer.

Calif., Redwood City—Union Ice Co., 354 Pine St., San Francisco, awarded contract for a 1 story, 100 x 126 ft. ice manufacturing plant here to W. W. Williamson, 320 Market St., San Francisco.

Calif., San Rafael — Constructing Quartermaster, c/o H. B. Nurse, plans a 3 year construction program to include five 2 story barracks buildings, warehouses, shops, etc., at Bombing Base here. Estimated cost $5,000,000.

Calif., Watsonville—Fruit Growers Cold Storage Co., 16 Wall St., awarded contract for the construction of a cold storage plant on Salinas Rd. to P. T. Wallstrum, 217 Center St., Watsonville. Estimated cost $180,000.

Ind., Auburn—School Commissioners, awarded contract for improvements to power plant including water supply service, hot water heater to A. C. Achmier, Auburn. Estimated cost $50,000.

Ind., Auburn—U. G. Souder, awarded contract for addition to power plant for hospital, to Yoder & Loutzenheiser, Auburn. Estimated cost $40,000. Equipment not purchased.

Ind., Newcastle—State will receive bids until May 26 for addition to power plant including feed water boiler, mechanical equipment, boiler setting, etc. Estimated cost $41,000. Foltz, Osler & Thompson, Architects Bldg., Indianapolis, are engineers.

Ind., Fort Wayne—Indiana School for Feeble Minded, awarded contract for the construction of a power plant to Buesching & Hagerman Co., 402 East Superior St. Estimated total cost $195,000.

Kan., Colby—Syms-Shafer Grocery Co., will soon award contract for the construction of a 2 story, 60 x 237 ft. cold storage plant. Estimated cost, including equipment, $45,000. B. H. Byrnes, 312 National Bank of America Bldg., Salina, is architect.

Mass., Boston—Edison Electric Illuminating Co., 39 Boylston St., awarded general contract for addition to steam heating plant at Kneeland and Utica Sts., to W. A. and H. A. Root Co., 750 Stuart St. Estimated cost $750,000.

Mass., Boston—Bureau of Yards & Docks, Navy Dept., Washington, D. C., awarded contract for motor generator sets and switchboard to F. A. Mazzur Co., Inc., 141 Milk St. Estimated cost $60,000.

Mass., Boylston—Worcester County Tuberculosis Hospital, E. W. Glidden, received lowest bid for the construction of a hospital nurses' home, power house and service building at Hunting Farm from J. P. Keating, 58 Front St., Worcester. $938,700.

Mass., Greenfield—Greenfield Ice & Trucking Co., R. C. Phelps, 50 Union St., is receiving bids for the construction of an artificial ice plant on Bernardston Rd. Estimated cost $40,000. R. E. Palmer, 58 Suffolk St., Holyoke, is engineer.

Mass., Monson — Dept. of Mental Diseases, plans the construction of an infirmary, also storehouse, including refrigeration system at State Hospital. Estimated total cost $225,000. Architect not selected.

Mass., Norfolk—Dept. of Correction, is having preliminary plans prepared for the construction of state prison colony. Estimated cost $1,500,000. McLaughlin & Burr, 88 Tremont St., Boston, are architects.

Mass., Springfield — Commanding Officer, Springfield Armory, awarded contract for replacement of steam boiler plant at Hill Shops, Springfield Armory, to A. D. Granger Co., Inc., 15 Park Row, New York. $72,444.

Mass., Waverly—Dept. of Mental Diseases will soon receive bids for improvements to heating plant including new turbine equipment at W. E. Fernald State School. Estimated cost $60,000. E. C. Brown Co., 77 Summer St., Boston, is engineer.

Mass., Wrentham—Dept. of Mental Diseases, appropriated $147,500 for the construction of a heating plant and employees' building at Wrentham State School. Architect not selected.

Mich., St. Joseph—City awarded contract for a waterworks filtration plant and pumping station to Lovering-Longbotham Co., Ann Arbor. $129,639. Equipment will be let later.

Miss., Jackson—State Insane Hospital c/o State Hospital Removal, Improvement & Land Sale Commission, C. Gordon, Secy., will receive bids until May 29 (extended date) for a group of buildings including power generator sets, etc. N. W. Overstreet, Mississippi Fire Insurance Bldg., is architect. V. B. Smith, Jr., Gulfport, is associate architect.

Missouri—Missouri General Assembly, passed appropriations for building projects at various state institutions, including light, heat and power plant at State Hospital No. 1, Fulton, $292,000; power plant at Missouri State School, Marshall, $190,000.

N. J., Asbury Park—Wilson & Co., 900 Springwood Ave., awarded contract for alterations to cold storage plant to Hall Carpenter Co., Inc., 917 3rd Ave., Asbury Park. Estimated cost $40,000.

N. J., Elizabeth—Bd. of Chosen Freeholders, Court House, will receive bids until June 8 for altering and new 15 story addition to court house including steam heating and ventilation systems, boilers, elevators, etc., at Broad St. and Rahway Ave. Estimated cost $1,000,000. Oakley & Son, 1259 Clinton Pl., are architects. P. West, 13 Central Ave., Newark, is engineer.

N. J., Newark—Bd. of Education, City Hall, is having preliminary plans prepared for the construction of a 4 story junior and senior high school, including power plant, etc., on Chancellor Ave. Estimated cost $1,000,000. Guilbert & Betelle, 20 Branford Pl., are architects.

N. Y., New York—Dept. of Hospitals, Municipal Bldg., will receive bids after June 15 for addition to boiler house and stack at Welfare Island. W. H. Gompert, 101 Park Ave., is architect. K. M. Murchison, 101 Park Ave., is engineer.

N. Y., New York—General Realty & Utilities Co., 285 Madison Ave., will build an apartment building at Columbus Ave. and 67th St. Estimated cost $10,000,000. Private plans. Work will be done by separate contracts. Maturity October or later.

N. Y., New York—Transit Commission awarded contract for the construction of a cold storage warehouse and railroad viaduct at 450 West 14th St. to Aronberg-Fried Co., Inc., 21 East 40th St. $509,227.

S. D., Vermilion—City is having plans prepared for the construction of an electric light and power plant. Estimated total cost including equipment, $85,000.

Texas—Central Power & Light Co., Alamo National Bank of Commerce Bldg., San Antonio, purchased Arkansas-Rockport Light, Ice & Power Co.'s properties at Aransas Pass, Ingleside, Rockport, Fulton and Bayside. Surveys will be made and considerable improvements, including enlargements, new machinery and equipment, etc. Private plans.

Tex., Camp Normoyle—Constructing Quartermaster, Normoyle Depot, plans repairs to power plant here.

Tex., Eagle Pass — Central Power & Light Co., National Bank of Commerce Bldg., San Antonio, awarded contract for three large vertical waterwheel generators, 4,000 kw. each, for hydro-electric plant now under construction in connection with irrigation project in Maverick County near here, to Westinghouse Electric & Mfg. Co., 150 Broadway, New York, N. Y. $125,000.

Tex., Fort Worth—Texas & Pacific Ry. Co., Dallas, awarded contract for the construction of seven buildings for clearing, repairing, electrical charging and general upkeep of coaches including boiler room and compressor room, coal and scrap bins, store and oil house, etc., here, to F. A. Mote, Constr. Industrial Bldg., Dallas. E. F. Mitchell, Dallas, is chief engineer.

Ont., Picton—Prince Edward County Fruit Growers, awarded contract for the construction of a cold storage plant for fruits and vegetables including artificial refrigeration, etc., to J. Stacey, Quinte St., Trenton. Estimated cost $100,000.

Ont., Thedford—J. K. Laehn, 129 King St. W., Kitchener, Engr., preparing plans for a cold storage plant. Estimated cost $100,000. Interested in prices on complete equipment.

Equipment Wanted

Air Compressor—Pasadena, Calif.—B. Chamberlain, Clk., will receive bids until June 5 for rotary air compressor for sewage disposal plant near Alhambra.

Air Compressors, Electric Motors—Boston, Mass.—J. Amirault, 101 Pearl St., plans to purchase air compressors, single ph. electric motors, etc.

Alternator and Condensing Plant — Sydney, Australia—New South Wales Government Railways, will receive bids until July 8 for one 2,500 kw. alternator, also until July 22 for condensing plant for Lithgow power station.

Boiler—Jefferson Depot, Ind.—Constructing Quartermaster, plans the installation of a boiler, etc., here.

Boiler — Fort Hoyle, Md. — Constructing Quartermaster, plans the installation of a boiler in central heating plant.

Boiler—Everett, Mass. (br. Boston)—Everett Factories Corp., 210 Broadway, plans to purchase a 15 hp. boiler, self contained, Scotch or locomotive type, 50 lb. pressure.

Boiler—Clinton, N. J.—Dept. of Institutions & Agencies, State Office Bldg., Trenton, will receive bids until May 29 for furnishing and installing an 80 hp. boiler and underground service conduits at New Jersey Reformatory for Women here. Estimated cost $25,000.

Boilers—Toronto, Ont.—City, W. J. Stewart, Mayor, City Hall, will receive bids until June 16 for supply and erection of eight water tube steam boilers in John St. pumping station.

Engines—Chilkoot Barracks, Alaska—Constructing Quartermaster, Fort Mason, San Francisco, Calif., will receive bids until June 1 for furnishing and installing three 75 hp. Diesel engines, direct connected to a.c. generators, 3 ph., 2300 v., 60 cycle, automatic generator voltage regulator, complete switchboard and accessories here.

Generator Set—Lachine, Que.—City, Hector Daoust, Clk., will receive bids until June 8 for a Diesel engine driven generator set.

Pumps—Lynn, Mass.—H. R. C., P. O. Box 304, plans to purchase two centrifugal pumps, 2, 2½ or 3 in. with or without motors.

Transformers, Etc.—Cleveland, O.—City will receive bids until May 29 for a turbine cylinder for Allis-Chalmers turbine No. 3, also power transformers, etc.

Industrial Projects

Conn., Bridgeport—Jenkins Valve Co., 510 Main St., awarded contract for the construction of a 1 story, 65 x 65 ft. addition to plant on Railroad Ave., to Hewlett Co., 886 Main St. Estimated cost to exceed $40,000 including equipment.

Mass., Taunton—Taunton Pearl Works, 35 Vernon St., is having revised plans prepared for a 2 story plant. Estimated cost $50,000. Jackson & Moreland, Park Sq. Bldg., Boston, are architects.

N. J., East Rutherford—J. T. Camlet, 26 Piaget Ave., Clifton, Archt., will receive bids about June 1 for the construction of a 2 story, 30 x 70 ft. factory on Mozart St. for East Rutherford Syringe Co., 75 Mozart St. Estimated cost $40,000.

O., Cleveland—American Multigraph Co., J. E. Rodgers, Pres., is receiving bids for the construction of a 1 story, 580 x 620 ft. factory, office and power plant, 650 hp. on Babbitt Rd. Estimated cost $1,000,000. Ernest McGeorge, Midland Bank Bldg., is architect and engineer.

O., Cleveland—Otis Steel Co., L. C. Parrott, Pur. Agt., 3341 Jennings Rd., is receiving bids for foundation and side of 1 story, 90 x 240 ft. steel mill at 601 Clark Ave. Estimated cost $250,000 Structural steel contract let.

O., Fairport Harbor—Diamond Alkali Co. has started foundation work for a 1 story, 90 x 230 ft. mill. Estimated cost $100,00. Private plans.

O., Salem—Mullins Mfg. Co., plans the construction of a new continuous electrical porcelain enameling furnace, including new press equipment, sand blasting units, mill equipment for enameling complete conveyor apparatus for production line and various welding devices on Depot St. Estimated cost $175,000.

Pa., Pittsburgh—Iron City Oil Corp., W. A. Rodgers, V. Pres. and Mgr., 6800 Kelly St., is having preliminary plans prepared for a warehouse and loading platform. C. J. Pellegrini, 205 North Highland Ave., is architect.

Pa., Pittsburgh—F. Tinker & Sons, 5649 Berlin Way, (rolling mill supplies) awarded contract for a 1 story, 55 x 100 ft. factory at 5600 Butler St., to David Gittings, 7732 Hamilton Ave. Estimated cost $50,000.

Tex., Corpus Christi—Houston Oil Co., Petroleum Bldg., Houston, is receiving bids for enlargement of present refinery including several large steel retaining (storage) tanks, additional equipment, etc., here. Estimated cost $1,000,000. Private plans.

Ont., Petrolea—Canadian Oil Companies Ltd., C. A. Hale, Ch. Engr., has work under way on the construction of a new wax still, steel storage tanks and condensers. Estimated cost $25,000. Interested in prices on complete equipment.